4 Jan '10

HOW PLANTS LIVE AND WORK.

By ELEANOR HUGHES-GIBB.

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A SIMPLE INTRODUCTION TO REAL LIFE IN THE PLANT-WORLD. BASED ON LESSONS ORIGINALLY GIVEN TO COUNTRY CHILDREN.

BY

ELEANOR HUGHES-GIBB.

WITH ILLUSTRATIONS.

LONDON:
CHARLES GRIFFIN & COMPANY, LTD.
EXETER STREET, STRAND.
1896.

Printed by Ballantyne, Hanson & Co.
At the Ballantyne Press

EXPLANATORY PREFACE.

THE study of Plant-life has, for many years, been one of the keenest and most unfailing pleasures in my life.

The companionship of all the green things on the earth has always been felt by me to be a very real one; and the loneliest of country walks becomes bright and cheerful when one's little friends peep out from the hedge-rows, or look up from the short downland grass as if expecting a nod and a word of recognition and greeting.

I took the trouble, during one summer, to become personally acquainted with every species of the umbelliferous family which grew anywhere within reach. No very easy task; but I have been amply rewarded by the pleasant conviction that they are my fast friends for life, and warmly appreciate my discriminating glance of recognition, in place of the usual careless look and hasty generalisation under the very comprehensive (as thus applied) term of "Hemlock!"

It is, however, worth while trying to know something more than the names of one's little friends; to enter into their lives, and to understand their constitution and manner of growth; to appreciate their marvels of mechanism and symmetry, and to trace out the same laws and the same central plan and idea running through their simple existence

and our own more complex life. The pleasure of these studies and observations is a specially wholesome and elevating one; it braces, and yet soothes; it carries the mind away from itself and its own narrowness, and leads it out into the broad and breezy fields of natural science, whose wonders and delights are ever new, and can never weary or pall, for they are infinite. Like all pure and wholesome pleasures, this one soon prompts the mind which enjoys it to seek for sharers in its happiness. It is so natural and right to desire that others should sympathise and enjoy with us.

Children are very near to Mother Nature's heart. She loves them, and they return her love with a delightful, ardent affection. Could anything be easier than to interest a little child in botany, if only one does not use hard, incomprehensible terms, and if one allows the young eyes and fingers to work for themselves? Yet how many little village children, wandering through country lanes and fields, miss the precious, simple pleasures, inestimably beneficial in their purifying, elevating, and broadening effects upon the mind, which lie scattered along their path, in every little weed and wayside flower; each one of which, rightly understood, is like a beautiful story or poem, told in Mother Nature's own attractive fashion.

This pleasure, at least, need not be confined to children born in the so-called "upper classes"; and, with these thoughts in my mind, I began, in my leisure moments, early one spring, to make careful notes and preparations for a course of lessons to village children, which I hoped might awaken their interest in the dear green world around them, and teach them how to listen for Nature's voice, and to watch

her at work, intelligently, and with a fair hope of comprehending her.

The lessons were given in the summer of 1894 to a small class of village children, boys and girls; and the result encouraged me to believe that, with a little help and teaching, a little patient guidance, and a spark of enthusiasm on the part of some leisured lover of Nature, many a little soul might be led to make a friendship with the "Great Mother" which should last its life, much to its own happiness and advantage.

In the hope that some may be induced to undertake this charitable work, and may find my simple programme for a first course of lessons useful, I have amplified my notes and written them out in a more or less complete form, as they might be delivered. I may venture to suggest that it is my experience that anything which appeals to the eyes, as well as to the understanding, will be of the greatest service in interesting children and fixing their attention.

It would be well to procure, if possible, three photographs of the same person at various ages, as suggested in the course of the first lesson.

I found my microscope invaluable; and keen interest was aroused by the gift of a few peas, with the request that the children would keep them in damp moss until they germinated, and bring them back at the following lesson.

At the end of each lesson I append a note to the teacher, suggesting some small task which might be set to the children in the interval between the lessons, as a means of keeping their interest alive and of awakening their powers of observation. Of course it would be optional with the teacher to use these suggestions or not.

My aim throughout these pages has been to attain the utmost simplicity, so that every detail may be clear to the mind of a young child, and at the same time such careful accuracy that nothing learnt here shall ever have to be unlearned. I can only hope that, in some measure at least, I may have succeeded.

E. H. G.

March 1896.

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PART I.

LESSON I.

LIFE AND ITS SIGNS.

You have come to me, dear children, to hear something about plants. You want to know about their life, their habits, their needs, and their uses. I think I can promise you it will not be dull. I hope to show you how to enter into their lives, to sympathise with them, and to enjoy them in quite a new way.

But before coming to this, our own, subject we must talk a little about life in general.

You, children, have something to say about this, for you are some of Life's children, are you not? In other words, you are alive.

How do I know this? How can you prove to me that you are really living creatures?

If I watch and observe you for a little while I shall soon have three proofs which will be enough to convince me of the fact.

Mary, what has happened to the sleeves of your frock? Have you cut a piece off them? I know they were long enough when it was made for you, and now they are right up

"Oh, it's because I'm growing so fast! I've nearly outgrown my frock altogether!"

Then it is you who have altered, and not the frock? You **grow**; that is, your body gets larger in every direction. Does it alter in any other way?

Just look a moment at these three photographs I have brought with me. See this one first.

"Oh, what an ugly little baby!"

Well, yes! I can't say much for the poor little bald-headed creature. But now look at this.

"How sweet! What a pretty young lady!"

Yet she is the very same person as the little bald-headed baby! How she has changed, has she not? You wouldn't know her again.

Now see this third photograph.

"It is quite an old lady with such a wrinkled face. We don't like it as well as the pretty young lady!"

Yet she is the same person; and she and the little bald-headed baby are one! It is funny, is it not?

How these bodies of ours do change in appearance! Not only while we are young, and people say: "How she has grown! I shouldn't know her!" But all through life the process of change goes on.

This is what is really happening. All day long and every minute little tiny particles of your body are dying. You may think of them as the ashes of a fire which has burnt up a piece of coal or wood and leaves behind that which it cannot use. The fire is like your life; the white ash is the used-up particles of your body, which must be got rid of as quickly as possible. Your body has many most beautiful and wonderful arrangements for doing that. Your skin, with its countless tiny invisible "pores" or little openings, is one of Nature's plans for carrying away all the dead, waste matter of our bodies. That

wise the little pores will be choked, and it cannot do its work.

But now you are half frightened! You think that if these tiny particles of your body are dying every moment, it is rather a serious business, and you will soon be dead altogether!

Well, so you would be indeed if no new particles to take their place were made.

But every moment you are growing new **tissues,** as we say; making new flesh, new skin, new substance, to take the place of the used-up, dead matter which you are casting off. In seven years time you will have changed your whole body in this gradual way. The one you are wearing now will be all dead and gone, and you will have quite a new one! You see our body is only like a dress for our soul, a clothing of substance within which the invisible spirit may dwell, and Nature gives us a whole new dress every seven years! Only she does it by very slow degrees, so that there is no danger of our waking up one morning with a new body, which would certainly be startling! We only go on gradually, from day to day, *shedding* our old body in many silent ways, and forming daily new tissues; until our friends look at us and say: "How you have grown!" or, "How you have changed! I should not know you!" And here is the first proof which convinces me that you live.

I see that you **grow.**

And **growth** is a *sign of life.*

II. But now, tell me, children: can we **create?** that is, can we make *something* out of *nothing?*

No. We have not this power. God has given us the power to **convert** or change one thing into another, but not to create. Then, if we are continually casting off dead particles of our body and having to replace them with new substance, what are we to do it with?

It is clear we must **take in** something for the purpose. You can tell me, I am sure, what we take in?

What did you have for breakfast to-day? I suppose you "took in" a fair quantity of both food and drink?

Every moment I see your little chests moving—heaving gently up and down; what are you doing?

"Breathing, of course!"

Yes, you are breathing; in other words, "taking in" air. Food, water, air. These are the raw materials, as we may say, out of which our bodies are made.

But is it enough to take them in, merely? Is a piece of bread and butter or a potato like your flesh? No; you will have to **convert** or change it, and **make it like** your body, and then add it on to your own substance and so grow by it.

There are two Latin words "*ad*" and "*similis*"; the latter means "like" and the former "to." Together, you see, they will mean "like unto." We have a word which comes from them. It is a long word, but I want you to try to remember it. **Assimilation,** or making like. You must not merely take in food for your body, but must also **assimilate** it, or change it into a like substance with the rest of your body, or it will be of no use to you. You do this, you know, by your organs of digestion principally.

The **power of assimilation**, or of taking in substances, feeding on them, and "making them like" the body that uses them is a *second sign of life.*

I see that you grow. I see that you assimilate food, water, etc., and I am doubly sure that you are alive.

III. There is a third sign of life, however, which I am very conscious of in you. It is the one easiest to see, usually the first to be thought of. I wonder if any of you *could* sit absolutely still for ten minutes! I doubt it! To judge by your continual movements, you are very much alive.

Motion is a third sign of life. Motion, that is, without

any outside force to produce it. There is no life without some movement; although in Nature there is certainly much movement without life.

If we observe movements in any natural object, and are unable to account for them otherwise as being produced by a known force or law of inanimate Nature, we are led towards the conclusion that they are caused by *life*, and, in fact, that the object is alive.

I want you to notice two kinds of motion in our own bodies.

(1) Movements made by the will of the person moving; as when you lift your arm, nod your head, open your eyes. You do these things intentionally, and you need not do them unless you choose. We call these **voluntary** movements.

(2) Movements made without the will of the person moving; as when your heart beats, your lungs act, your blood flows, producing movements in your body which you cannot control. I once knew a little boy who said he could stop the beating of his heart; but when challenged to prove it with my hand over his heart, he looked rather foolish!

We call these movements which we cannot control **reflex** movements.

We have thought now of three signs of life. Three ways of proving that you are indeed amongst the number of Life's children.

What are they?

Growth, Power of Assimilation (you remember the meaning of that long word, don't you?), and **Motion.** Keep these in your minds. We shall want them when we come to prove that plants are—no less than you—really and truly alive.

But now consider with me for a few moments what other

earth of ours. Mention any other living beings you can think of.

"A dog; a fowl; a snake; a fish; an oyster; a worm."

Good. These are all forms of animal life. Is their life quite like ours? They all agree with us in showing the three signs of life we have spoken of: growth, power of assimilation, and motion. And their movements are of both kinds—voluntary (with their will and intention) and reflex (without their will or control). Let us note some differences, however. Are worms or oysters, fishes or snakes, warm to your touch, like the fowl or the dog? Do they take the care for their young that is shown by the hen, which hatches her eggs with such patience, or the dog, which devotes herself to her helpless puppies?

Can a hen count, and will she know if you remove one of her eggs?

Can even a dog use its brain as we can, do difficult sums, or take in ideas of things he has never seen? No. His form of life is lower than ours. That of a fish is lower than his; that of an oyster lower still.

Is there any lower form of living beings, differing from these, and less gifted than the earth-worm? Yes, there are a vast number of animals far beneath the earth-worm; and, beneath these, we come at last to **plant**-life; **vegetable** life, as scientific men say.

The worm, and even the oyster, has the power of movement **at will.** The latter opens and shuts his shell intentionally and consciously.

Plants have no such power, we believe, in spite of curious examples of **reflex** action, which we must speak of later on, when I tell you of the sensitive plant, the little fly-catching sundew, etc.

This "vegetable life" is, then, on the whole, a lower form

signs we have spoken of: Growth, Power of Assimilation, and Motion. Looked at thus, we may see that plants are truly our **fellow creatures,** created, like ourselves, by the great Father in Heaven, even though they belong to a lower form of existence than ours. Let us love and study them as such, in the spirit of St. Francis of Assisi, who spoke to the birds and beasts as "brother" and "sister"; and even used this word to the elements, as when, on one occasion, being ordered to be cauterised for some bodily trouble, he begged "brother fire" to be gentle with him!

SUGGESTIONS TO THE TEACHER.

Let the teacher, as a preparation for the next lesson, give every child a few peas, and tell them to put these in damp moss until they germinate. (The peas might be soaked for a day previously, so as to hasten germination, and be brought packed in moss.) If the children are old enough, a small reward might be offered for the best written description of a germinating pea.

LESSON II.

GROWTH.

You will remember, children, what was the first of the three signs of life which we spoke of in our last lesson? It was **growth**, was it not? You have not, I am sure, forgotten the little bald-headed baby, and how it grew, so that you could not recognise it.

Well, we are to speak to-day about the growth of plants. But we cannot wholly separate this from their **assimilation** of food, or from **motion**, which are to form the subjects of future lessons. However, we shall keep as closely as we can to the subject of their growth to-day.

Infancy. The Plant in the Seed.—Let us go right back to the babyhood of the plant; see it in its cradle, so to speak. Children, how did each of *you* begin life?

As a tiny helpless infant, fed by your mother, did you not?

Yes. And the dog, the cat, and the rabbit all began life in much the same way, did they not?

Now how about a bird? a fish? a snake?

They were hatched from an egg you say. So they were. And this seems a little more like the beginning of plant-life. Let us take a bird's egg and a seed—that of a buttercup, for instance—and compare them. The egg has a firm shell, and the tiny seed is protected by a horny, shiny, outer covering, which, however, is entirely separate from itself.

Inside the shell of the egg is a thin skin.

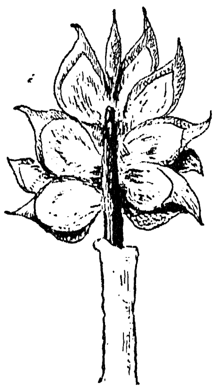
Inside the outer covering dwells the little seed, wearing a thin skin-coat.

Within the egg itself I find a small speck, which is the first beginning or **germ** of the little bird which is to be gradually formed in that egg.

Cutting the seed open I find one tiny dot which is the minute future buttercup plant, all folded up.

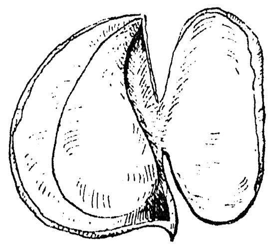
Closely pressed against the speck in the egg, and ready to be "assimilated," or taken in by that speck as it gradually

FIG. 1.



Head of buttercup fruit, cut in half to show the achenes* better. Slightly enlarged.

FIG. 2.



Achene of buttercup opened. The seed within its horny covering. Much magnified.

grows and develops, is the golden yolk, which is the food of the tiny bird until it comes forth into the world.

Round the wee folded germ of the buttercup is a hard, white, floury substance, which is the food of that tiny plant till it can shift for itself.

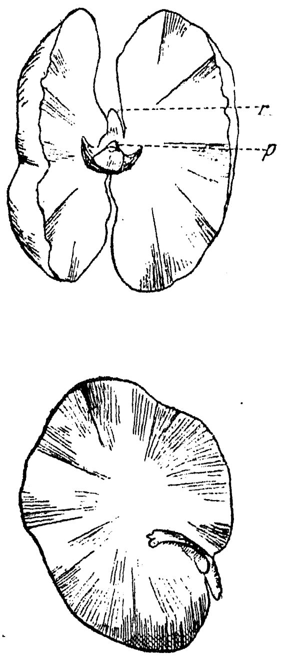
Thus we see that the birdie's egg and the seed of the buttercup bear a striking likeness the one to the other.

And are all seeds just like this one? Let us try. Examine a broad bean. Or a pea will do equally well if easier to get. The pod, you see, does duty for the protecting shell; what a soft downy lining it has! Dainty, luxurious bean! Well

* *Achene* is the botanical name for a dry, one-seeded vessel, which does not split open of itself when ripe; such are the seed-vessels of the buttercup.

may the French make their word for "comfortable" "well-provided-for," from their word for a **pod**! Could anything be more cosy? Now here is the shiny bean. Help him off, please, very carefully with his varnished skin-coat. What do you see inside?

FIG. 3.



a

b

a. Broad bean with seed-skin removed, pulled apart to show the "little hinge." *r.* Radicle. *p.* Plumule.

b. Broad bean in half. One of the "fat leaves."

Where is the white floury substance? Where the tiny, dot-like future plant?

Ah, what have you done now? No, don't look so startled. You have not broken it in two. See, it opens naturally by a little hinge, and divides into two fat halves, with a tiny little body pressed between them.

Can you guess what these two thick sides of the bean really are? Perhaps you will hardly be able to believe me at first, when I tell you that they are only the first pair of leaves of the young bean plant, the rest of whose diminutive body is squeezed up between them.

"But they are so fat and whitish, and leaves are usually so thin and green."

Yes, they *are* fat; but do you not see what their fatness really is?

In the buttercup the little **embryo**, as we call the baby-plant, was surrounded, as we saw, by a floury, white substance called the **perisperm** (from two words meaning

"white"). This was the food of the tiny plant, you remember.

But where is the food of the little bean-plant?

All the seed-skin is filled up with the embryo, or young plant; there is no perisperm or albumen. Where is the food?

Look at the two thick sides of the bean, which, as I have told you, are really the first pair of leaves. There is the food, stored away in the little plant itself, in those quaint, fat, most un-leaflike leaves.

Can you think of any other seed like the bean? Have you never played with acorns, I wonder, and pretended that the two yellow halves of the skinned seed were pats of butter? Certainly they are most unlike leaves! Yet such they truly are! And, indeed, when any seed divides readily into two halves, like the acorn or the bean, you may always suspect that they are truly a pair of leaves. But you want to ask something; what is it?

"We understand why those funny leaves are **fat**; but why are they yellow or white? why are they not green?

This is a wise question, and I must answer it more fully later on. I can only just explain to you now that the **green** leaves are the kitchens of the plant, where all the food is cooked at the great sun-fire. Now the food in the acorn and the bean has already been cooked and prepared by the mother plant on which the bean or the acorn grew; so it does not want cooking again. Therefore these leaves are **store-rooms**, not **kitchens**, and they stay underground and do not turn green.

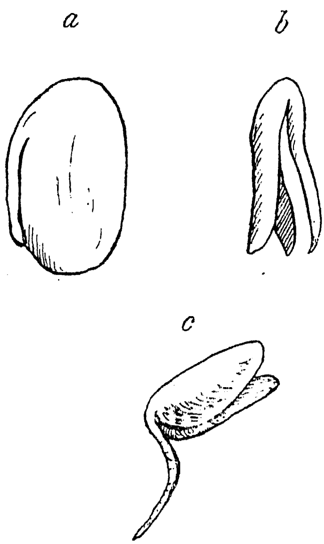
There is one more class of seeds that I want you to examine. The wallflower and the turnip, amongst many others, belong to this class. Let us take a pod of the common wallflower. It is ripe, and splits open of itself, showing the pretty transparent partition inside, which divides the rows of seeds from each other. The seeds are small, but with care I think we can get one of them out of his jacket.

Now what do you see?

"Why, it looks like a little plant, with two thin yellowish leaves, and his tail is turned back like a squirrel's, close to the edges of the leaves."

That little pointed "tail," as you call it, is the tiny root of the baby plant, and it *is* funny to see it tucked up so neatly and carefully. The leaves look yellowish-white now, but if you had put this little seed into the ground and allowed it to germinate, they would have come out of their brown covering not **yellow** but **green.** Try the experiment and see.

FIG. 4.



a. Wallflower seed magnified.
b. and *c.* Embryos of wallflower seed germinating; testa (or seed-skin) removed.

But now let us examine this pretty winged seed of the maple, which we must put in the same class (from the point of view of the provision of food for the little embryo) as the wallflower.

What do we see here?

"Oh, it is a dear little **green** plant with its leaves so prettily rolled up. But where is the food? Why are the leaves green and thin? Did you not tell us that the leaves of the bean were fat because they were full of food for the little plant, and white because the food was already cooked? But these leaves are green and thin; how will the little plant live then?"

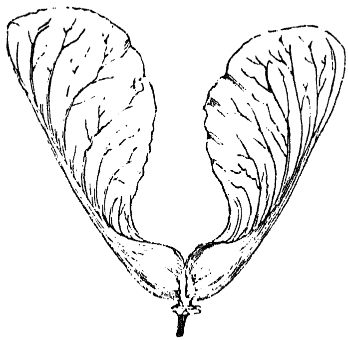
Patience, children, and I will answer. You are right; this poor little plant is apparently less well provided for than the comfortable buttercup embryo in its bed of albumen, or the

laid up for it by its parent plant; and, like poor little waifs and strays of London, it is early turned out to shift for itself.

But now, observe; with the necessity of shifting for itself Nature gives the capacity, or power, to do so. Why is it green, do you ask? Just because it has got to cook its own dinner, and, as I told you, only green leaves can do that.

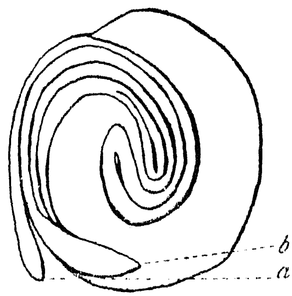
As soon as ever it breaks out of its seed-skin, or "ger-

FIG. 5.



The winged seed of the maple. Natural size.

FIG. 6.



Embryo of maple-seed, magnified. To show the manner of folding.

a. Tip of radicle.

b. Tip of cotyledons (or first seed-leaves).

minates" as we say, those small green leaves will begin work. The little root will hurry to provide the raw food out of the damp earth, and the green leaves will cook it at the great sun-fire, and so the small plant will, from its earliest infancy, be self-supporting.

How wonderfully Nature provides for all her children, does she not? and yet how differently she treats them. Some she seems to pet and coddle, sending them into the world with supplies of ready-cooked food, like the dear, wee, baby fish (trout fry) that I once saw, which were hatched each with a little bag of food attached to him, so that he might have time

to look about and see what a nice place this world is before he had to think how he should get his dinner.

Others, again, like this poor little maple, or the wallflower seedling, have got to set to work almost as soon as they are born!

But then, you see, Mother Nature knows what is best for each, and fits him for his work and place.

Now we have spoken of three classes of seeds.

Let me see if you can remember them.

(1) Those *with* albumen, like the tiny buttercup in his bed of white floury food. These we must call **albuminous** seeds.

(2) Those *without* albumen, but with *thick* seed-leaves, full of stored-up food, like the bean and the acorn.

(3) Those *without* albumen, and with *thin* seed-leaves, which contain no store of food to support the baby plant, like the independent little wallflower and turnip. These last two classes we must call **ex-albuminous**, which means "without albumen."

But now, children, you must not expect that all seeds which you may examine for yourselves will go quietly and without giving any trouble into one of these three classes.

Life's children are not like that; they won't be labelled neatly and put away in packets as easily as buttons and tapes. Some of them will give you trouble.

How would it be if I tried to divide all of you children into two classes: "good" and "bad"? James is certainly "good" and Fred is "bad," but what about Tom? He really is not a good boy, and yet I can't call him positively bad either; I suppose we must make another class for him. But then how about Frank? He is not quite so bad as Fred, yet not so good as Tom; must he have a class to himself also? Oh! this won't do at all. You see it would be endless.

will all agree with one or other of the three types I have given you, but often you will be puzzled by the way in which one class will seem to melt into another.

There may be a *large embryo* with just a *little albumen*, as in the nettle or the mallow seed; or a *tiny embryo* with *much albumen*, as we have seen in the buttercup. The leaves of the embryo may be *very thick*, as with the bean; rather *fleshy* like those of the sunflower; or *quite thin*, as in the case of the wallflower. You will find endless variety; but if you think of the three types of seeds which we have set before us, and try to remember, and also to look for yourselves how Mother Nature has provided for each, I think you will soon be able to understand something about her plan and intention for every little seed you examine, and to see how she has fitted and prepared each for his place.

SUGGESTIONS TO THE TEACHER.

Let the teacher encourage the children to make a collection of different seeds, putting them, as far as they are able, after examination, into the three classes described in the lesson.

A reward might be offered for the best collection, best arranged under the three classes.

LESSON III.

GROWTH (continued)—THE CHILDHOOD OF PLANTS, OR SEEDLING LIFE.

AFTER all, in our last lesson, we never even saw our little plant "out of the egg-shell," so to speak; never arrived at the first beginning of its growth! We spent all our time in observing Nature's preparations for the happy hour when the young plant should come forth from its death-like sleep in the seed, into light and life, and the sunshine and air of this bright world!

We must hasten on now and bring our little embryo plant through the first stage of the wonderful processes of its life and development.

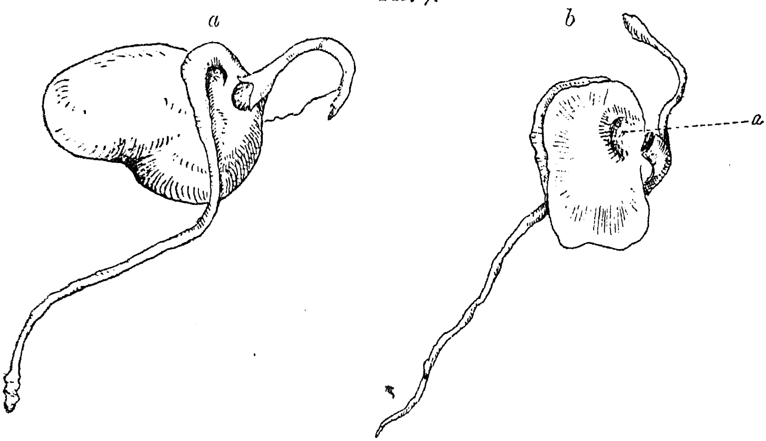
Germination.—The egg needs **warmth**, and, in some cases at all events (for instance, in that of the eggs of ducks and other aquatic birds) **damp**, to hatch it. The embryo requires both of these conditions to enable it to "germinate," that is, to come forth out of the seed as a young plant. Also some **air** is necessary to it for this purpose.

These are the three requisites for germination; *heat, moisture, air;* keep them carefully in memory.

Now let us watch a bean or pea germinate. The skin that covers it breaks (like the chipping of the egg-shell), a tiny white point comes forth, seems to look about it, and quickly buries its little nose in the ground. This is the **radicle**, the

se-fitting cap to his delicate tip, lest he should injure it as burrows with it like a mole. The cap, which is really a rt of him, is strong enough to bear the roughness it meets th. Do not expect, however, to be able to see this cap th the naked eye; you would need a microscope, and then *very* thin slice of the tip would show you the point of the ot, and the kind little protecting cap that covers it.

FIG. 7.



a. Germinating pea. *b*. Germinating pea cut in half, showing the depression where the head of the plumule rested, *a*.

But how does the "radicle" know that he must grow down into the earth to find food and fulfil his duties?

Ah! Mother Earth herself helps him there! She gives him a friendly pull.

She is constantly pulling *you*, or you would fly off into the sky. All bodies have what we call an "**attraction**" for one another, that is, each one pulls the other with greater or less force, and this tends to draw them together.

Thus the growing root is drawn by attraction towards the centre of the earth.

with a bent neck begins to struggle upwards. This is the **plumule**, and is the small beginning of the future bean plant. Some children I was teaching once used to say:

"The *radicle* is the *root*
And the *plumule* is the *shoot*."

That helped them to remember, you see.

But how is it that the plumule grows upwards? Does not the earth pull it too? Ah! this is one of the secrets of Nature. We do not know how the little plant finds strength to grow upwards in spite of the earth's attraction; but we know that the whisper which prompts it to do so is a wise one, for sunlight and air are indispensable to its life. You know already that the sun is the great fire, and the green leaves the kitchen where all the plant's food is prepared.

But until the green leaves are old enough to do the cooking, what does the baby bean live upon?

I have told you before of the two thick seed-leaves, with their store of prepared food. They have no cooking to do, for the food is ready for use, stored up in their thick sides; so they do not need sunlight or air, and may be content to stay below, unless they should be dragged up out of the ground by the efforts of that little arching neck which is trying to uplift the plumule. We call that little bent white stalk the **caulicle.**

Why does it arch so?

Think. If you have ever played in a hay-field and been buried in the hay, how did you get out? Did you push your way out nose first? I expect not. I expect you protected the delicate skin of your face by a bent neck and back, as the little seedling protects its delicate plumule.

How does it straighten itself? Well, the underneath part of the curved stem sets to work to grow much faster than the upper part of the curve, and so the stem is soon

explain to you later. At present, I can only say it grows faster because it is less exposed to the light. And this brings me to the fact, which I can only mention now, that growth takes place (with plants) principally at night, because there is less light then, and light, whilst it helps the food-making business, rather hinders growth. So that which is often said of children, is really true of plants, they "grow in their sleep."

But now we must speak of **the full-grown plant.**

Imagine the little seedling grown to be a large plant. The tiny radicle has branched out into numbers of rootlets and fibres; the plumule has developed into many stems and leaves; the food in the seed-leaves has long been used up, and the plant can provide for itself.

Two duties now present themselves to it as a full-grown plant. They are:

(1) The duty of **laying up a store** of food for future use.

(2) The duty of **reproduction,** that is, of producing new plants of its own species, to take its place when it is dead, and carry on the race of beans.

How the plant makes its food, we are to learn later; but when made, where can it be stored away? Has the bean a storehouse or a barn, cupboards or cellars, where it can lay up food?

Just underneath the skin of human beings there is a thin layer of fat, which is capable of being used for the nourishment of the body: a store laid by for a rainy day! Notice how thin we become in illness; we have used up this store. So in plants, just underneath the skin of the stem there is a like store of food. This feeds the leaf-buds, and provides ready-made food when they want to grow.

Some plants have large storehouses as well as this. They are in all parts of the plant; sometimes in underground

of the potato; sometimes in the root, as with the turnip or carrot; sometimes in the stem, as with the sugar-cane. Always a special provision has to be made in the seed for the new little plant.

You have not forgotten the buttercup embryo in its bed of albumen, or the fat sides of the seedling bean? but even such poor ill-provided creatures as the wallflower's or the maple's baby plants appear to be, are not really so mother-forgotten as they seem. A store of nourishing albumen *was* laid up in the tiny green **ovule** or unripe seed; but before the seed had ripened and was ready to germinate, all the albumen had been used up, and the tiny plant was thrown, as you see, on its own resources.

All this brings me naturally to the second business of the full-grown plant, namely:

THE REPRODUCTION OF ITS KIND.

In this course of lessons there is no time to enter into this interesting subject, and we can only just mention it here. I want you, however, to notice the great alteration that takes place in the parts of a plant when they have a new duty to perform. For I must tell you that those parts of the plant which you call the flower, and from which the seeds come, are truly and really **leaves,** altered so as to do a different work. It is strange, it is hardly to be believed, you think, that the brilliantly coloured, and often curiously shaped petals of the flower (the **flower**-leaves) are really only **green** leaves, changed so as to be capable of performing a different duty. But so it is, and you may have proof of it from your own observation, if you care to use your eyes long and patiently enough. I have myself observed more than one specimen of **Trollius**, or globe-flower (like a big globe-shaped buttercup), in which a leaf, half of which was **yellow** and **petal-shaped,** and half **green** and **leaf-shaped,** had grown midway up the stem. Does not this teach us

that petals and green leaves are truly one and the same thing, altered so as to do a different duty?

Fig. 8.

Trollius with abnormal leaves, *a. a.*

I think you must often have observed the little thread-like *stamens*, which are easily seen in many flowers, clustering together in the centre of the blossom, encircled by the coloured leaves; and, probably, you have often dusted your fingers with their yellow powder, or *pollen*.

In the middle of them, and just above the envelope or covering which contains the seeds, stands the *pistil*—the centre-piece of the whole flower—often looking like a thicker thread, with a small nob at its end.

These important little organs, whose duties are connected with the production of the seeds of the plant, are—strange as it may appear—simply "modified" or altered leaves.

The subject is intensely interesting, but we cannot talk of it this time. If you become really interested in the life-history of the plant, the study of its flowers and their marvels of beauty and wonderful arrangement may delight you at some future time.

SUGGESTION TO THE TEACHER.

Let the teacher request the children to make a collection of the various roots of plants, dividing them into two classes, viz:

(1) Those which contain storage places for food (as the onion, the bulbous buttercup, etc.); and

(2) Those which have no such arrangement.

A reward could be offered, as before, for the best collection, if desirable.

LESSON IV.

ASSIMILATION.

We come now to the second of our three selected "signs of life."

You have not forgotten our talk about this body of ours which so constantly needs to be renewed, and how we have to take in food, water, etc., and **assimilate** or **make** it **like** the rest of our body?

Now we must study the bodies of plants and their organs of assimilation.

What do I mean by an *organ?* *Not* an instrument of music, certainly, but an instrument nevertheless.

An "organ," in this sense, is any part of our body which we use for a special purpose, to do a certain work. The eye is the organ of sight, the ear the organ of hearing, and so forth.

You and I have many parts of our body which we only use for one special purpose; and as these organs have only one work to do, they do it more perfectly than if they had several such offices to perform. The number and perfection of our organs is a sign that we are high in the "scale of being."

[*But you do not quite know what I mean by this.

FOOTNOTE FOR TEACHERS.

* The portion of this lesson between this bracket and that on page 26 may be omitted if the lesson is thought too long, or the passage too difficult or likely to prove uninteresting. It is, indeed, a parenthesis in this place, but it is inserted partly for the sake of preparing the way for things that must be explained further on, especially in the second part of this

Imagine, then, that you see a great ladder set up on earth. You and I, with all human creatures, are at the top; let us go down it and see what we shall pass. We come first to the monkeys; so like little men, are they not? And some of them with such a sad, wistful expression, as if they were longing for something which they could never quite reach. Numberless animals crowd the steps as we go lower down; lions and tigers, dogs, elephants, cows, horses, sheep and goats; far too many beasts for us to mention by name. Great whales come next; and I notice a kangaroo, with some other animals, a little lower down.

Now we come to the birds; what a flapping of great and little wings!

Here are snakes and lizards, and, a little below them, toads and frogs.

Now we have reached the fish. Perhaps you think the whales ought to have been here, but their true place is higher, as we saw.

Lower still we come to oysters and snails.

Here are crabs, and now follow spiders and insects of all kinds. I am afraid you think this is unpleasant company! Worms are wriggling at our feet!

You will like the pretty starfish better, and the jelly-fish

book, and partly because it is thought that the first mention of differentiation in organisms ought to be the signal for a general view—however cursory—of that order of ascent in Nature which works upward from the wholly undifferentiated organless Moneron to the highly complex arrangement of delicate organs which compose the human body.

The *ladder* simile has been used, rather than that of the branching tree (which is recommended by Mr. Clodd in his *Story of Creation*, as giving a truer view of the evolution and place of various life-forms), because it is simpler to a child's understanding, requires less explanation, and gives a sufficient idea of the order in Nature for present purposes.

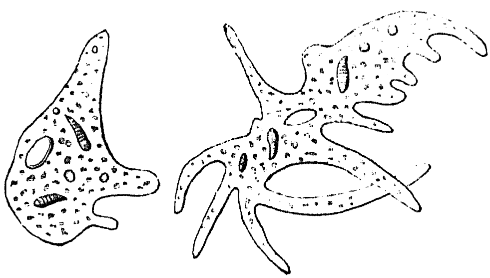
A few links in the chain, which seem likely to puzzle the child, or to be unknown to it, have also been omitted in this very general and cursory glance through the animal and vegetable kingdoms in their order.

and sea-anemones which follow will delight you, as will also the little coral-builders.

Lower still we find the sponges.

Below these there are still some forms of animal life, but you will be unable to give them names. These are like tiny balls of perforated shell with delicate feelers, floating in the water; but there are some lower down which look like simple lumps of jelly, without form or shape. You can scarcely believe that they are indeed living beings.

FIG. 6.



Amoebae, highly magnified. Examples of the "lumps of jelly" at the bottom of the animal kingdom, without definite form or organs.

Now we are at the bottom of this great ladder of life, or "scale of being," as regards the animal world.

Look again at these sticky lumps of jelly without even a definite shape, and with every part of their bodies alike, and no part specially fitted for a special purpose—in fact, without **organs.** They have *no mouth*, but take in food all over them—anywhere! *No lungs*, but they breathe all over their bodies—anywhere! Compare them with yourself, and you will easily understand what I said about the number and perfection of our organs being a sign that we are high in the scale of being.

But our business is with the plant world and *its* organs, and I only led you down the scale of animal life because I

thought you would see the difference better (in your present state of knowledge) between yourself and a shapeless lump of jelly, than between a daisy and a fungus; and would therefore understand better what I wanted to impress upon you as to the perfecting and multiplying of the organs of beings as we go up the scale of life.

Side by side with this great ladder of animal life which we descended just now, you may imagine another—the scale of plant life.

At the very bottom of these two ladders, plants and animals are so much alike that it is sometimes very hard for even clever men of science to determine to which kingdom—the animal or vegetable—a being belongs. When you think of the shapeless little lumps of jelly we found at the bottom of the animal kingdom, you will hardly wonder at this, I think.

If we go *up* the scale of being in the vegetable world, we shall come first to the sea-weeds and *Algæ* or water-weeds of all kinds—the lowest of these like little specks of jelly joined together in rows.

A little higher we come to the *Fungi*. The "mould" which grows on your jam and other things, sometimes, when it finds suitable conditions, is a tiny fungus, and belongs to these. (Even this, you see, is also one of Life's Children, and has its own work to do for her, though you may not admire it!) A pleasanter member of this group is the mushroom which you gather in the fields on dewy mornings.

Mosses come next; and above them the graceful ferns.

Higher up we find pine trees.

Above these come palms, wheat and barley, grasses and beautiful lilies.

Higher yet are oaks and willows.

Beautiful flowers, exquisite in colour, shape, and smell, now delight us. We choose violets and roses to admire amongst them.

A little above these the graceful convolvulus twines, and the primrose puts forth its creamy flowers. At the top of all you will be surprised—but surely not sorry—to find the dear little homely **daisy** as Queen!

In these lessons I have not been able to tell you anything about the arrangement or **classification** of plants, so you

FIG. 10.

A forest of little mould plants growing on a decayed leaf; seen through the microscope.

don't understand the reason for the order in which we found the plants; but the fact to be remembered is always this: that the higher up the scale the being is—whether plant or animal—the more perfect and the more numerous are its organs.]

Certain organs there are, however, which all living creatures must possess. They are the first to be developed,

for they are necessary to the very existence of the plant or animal. Remembering all that we have said of the continual wearing away of our bodies, and the constant need of renewing their substance, I am sure that you will guess at once that I am speaking of the organs of assimilation, or, as we had better call them, **organs of nutrition,** that is, of feeding, because their business is, first to take in the food, and then to assimilate it.

Even the little mould-fungus on your jam has these organs and knows how to use them. It is true it cannot cook or prepare its own food out of substances found in the earth, air, or water, as the plants with green leaves can do; but it knows how to eat and enjoy your jam, or your cheese, or whatever its tiny seeds have lighted upon and found to be suitable, nicely cooked food, ready for it to assimilate!

It likes a nice damp atmosphere to grow in, so, if you don't like this small fungus, you must keep your food in a dry place, and boil your jam well, covering it carefully so as to shut out the air with the tiny seeds that float in it, and then you may hope to keep your food for your own eating!

Let us now see which are these indispensable "organs of nutrition."

They are three in number.

(1) The root; (2) The stem; (3) The leaves. If, by way of illustration, we compare a plant to a house full of hungry people, the root will be the back door, where the butcher, the baker, and the milkman bring supplies; the stem will be the passage; and the green leaves the kitchen, where all the cooking is done, and the raw materials are converted into suitable food for the party.

Or suppose we compare the plant with our own body, then the root will be like the mouth; the stem will represent the throat; and the green leaves will be the stomach, where the food is digested and made fit to nourish the body.

So, you see, the root takes in or **absorbs** the raw material. We may call it an **organ of absorption**.

The green leaves prepare and assimilate it.

We may call them **organs of assimilation.**

Together, these are the **organs of nutrition.**

I must, however, tell you that when the stem is green some of the cooking is done in it, as well as in the leaves. "Most improper to do the cooking in the passage!" I am afraid you will say; but Nature is very economical, and wherever there are green portions of a plant that *can* cook, she will make them take their share, even though they may have other work to do besides! I must also tell you that both passage and kitchen—you know I mean the stem and the leaves—have numbers of tiny little windows in them, through which air and vapours are taken in. These tiny windows can be opened and shut according to the requirements of the plant. They are called **stomata**, from a Greek word meaning "mouth."

The gases and vapours help to nourish the plant, so we must regard the stem and leaves as organs of absorption as well as of assimilation.

But I fancy you are longing all this time to know what plants really have for their dinner, and you wish you could peep into their kitchens and see the food preparing.

I am afraid that you will be disappointed to hear that plants cannot eat solid food. I do not think any of you would care to be obliged to live entirely on liquid things, though tiny little babies seem contented enough with their bottles! but no plant can ever take in the least morsel of solid food. It could not even manage a dose of that medicine the doctor sent you, which has "to be well shaken before taken," because of the sediment which settles at the bottom of the bottle. You do not think there is much to regret in that, perhaps? On the other hand, if you melt up a lump of sugar in a tumbler of water, so that it entirely disappears,

the plant wont say "no" to that. You admire its taste? But it is not a matter of taste or choice, but of necessity. The powder in the dose of medicine was "in suspension" in the liquid; shake as you might, you could not make it disappear like the sugar. As soon as you put the bottle down, the powder sank to the bottom.

The sugar, on the contrary, was "in solution" in the water —wholly melted up, and so mingled with the liquid that you could no more distinguish or separate one from the other. Now plants can absorb things **in solution** in liquids, but not things which are merely **in suspension** therein. The food of plants, taken in by the roots, consists, then, entirely of water with various substances "in solution"—or melted up—therein.

I told you, however, that the leaves and stem, besides their work of preparing the food brought to them from the root, have also to take in something through their little windows or "stomata."

What could come in through these little windows? What comes into your room when you open the window?

"Only air," you say.

No; not air *only*, but also everything that the air can contain or carry.

Why does mother shut the window when it has been raining heavily and there is a white mist rising?

"Oh, it is damp, you know!"

Yes; the air is full of tiny, wee drops of water, too small to see except as "vapour" or "mist," which is really the same thing as the steam clouds which you often watch coming out of the spout of the kettle.

So the air is capable of containing water.

Now tell me, children, did you ever pass gas-works or a tallow factory? If so, did you not hold your nose as you went by? Why?

"Because there was such a nasty smell!"

But what is smell, children? I see nothing! there is only air all round me.

"But it is in the air; you can't see it!"

Yes, it is *in* the air, just as the sugar was in the water, and your tongue could taste it, though your eyes could not see it. Air is a fluid, just as water is; and it can hold things "in solution," so to speak, just as water can. Your nose perceives the gas in the air, though your eyes do not see it.

"And can air hold things, for a time, 'in suspension' too, as water can?"

Look at the dust blowing! There is your answer. Does it not remind you of the sediment in the bottle, mixed up with the water by the shaking of the bottle, but settling to the bottom when all becomes quiet?

Now when the plant opens the tiny windows of its stem and leaves, the air can enter with its vapours and its gases, but the dust must stay outside, for it is not melted up in the liquid air, so to speak, but is still in a solid form.

All it can do is to choke up the little windows and make the poor plant very uncomfortable and unhealthy, until the next shower of rain comes and washes it clean again.

So we learn that the food of plants consists of water, with various substances in solution, taken up by the roots, and of gases and vapours taken in by the leaves. Exactly what these substances and gases are, you shall hear later on.

Meanwhile, having seen the raw materials delivered at the door, we must leave the account of the cooking and storing of them for our next lesson.

SUGGESTION TO THE TEACHER.

Let the children make observation on the different substances which are soluble in water and those which water will only hold in suspension if introduced into it as powder. Written lists might be made, if the children are old enough, and rewards offered as before.

LESSON V.

ASSIMILATION (continued)—THE GREEN FACTORIES.

You, who live in this quiet village, with its green lanes and fields, have perhaps never been in a great manufacturing town, black with the soot from its many tall chimneys; you have never been inside a factory of any kind, or heard the whirr of its noisy wheels. If I could take you into one, in some magical fashion, this minute, I believe you would soon want to come out again. You would be half deafened by the noise, wholly bewildered by the innumerable revolving wheels and awful-looking machinery in unceasing movement; your head would ache and your eyes be dazzled and tired, and you would soon be longing for your quiet, breezy fields again.

This is the sort of place where man does his manufacturing business, where he makes the things required for his various necessities and pleasures.

Now shall we look into some of nature's factories, and see how she does her work?

Where shall we find them?

Why, you live in the midst of them; you cannot open door or window without seeing—perhaps almost touching—them. That green field is a perfect town of them. Yes, children, every green leaf, from the rose branch that taps at your window pane to the weed beside your doorstep, is one of nature's factories, and is hard at work all day long.

If you went into one of these towns at night, should you expect still to hear the whirr of wheels and the clanking of machinery? No. Man must rest; he cannot labour on unceasingly. And the God who constituted him thus, who gives you your refreshing sleep, the God of Nature, bids His green world also rest at night.

Light is necessary for the manufacturing process in the leaves, and when the light is withdrawn the work must cease.

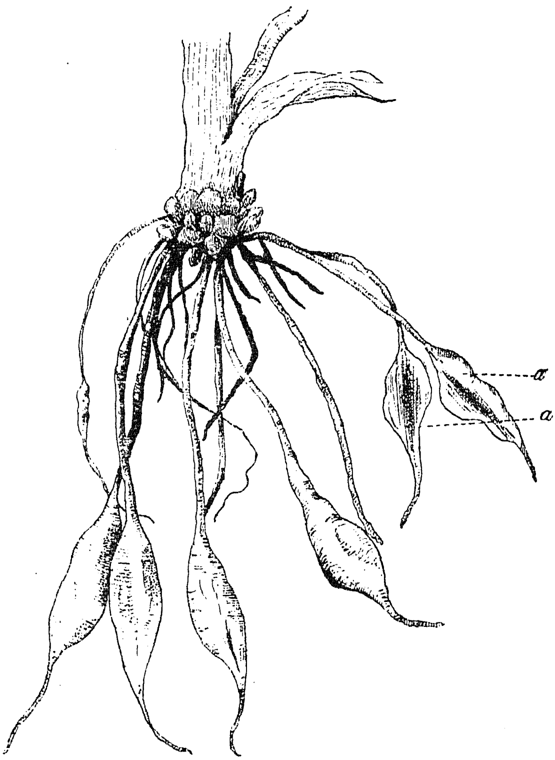
I do not say that no work goes on at night. Your heart and your lungs do not rest when you sleep, nor do you cease growing. The plant is busy using up the store of food which it has drawn from the earth and air, and prepared during the day by the help of the blessed sunlight. It is busy growing; but it is resting from the labours of the day. Its work is different, and a change of work is often the truest rest. The plant does not, as a rule (except in the case of young seedlings with few leaves and rapid growth) use up for its immediate needs all the food which it prepared during the day; even though during the whole twenty-four hours the growth goes on with greater or less vigour, and a portion of the food prepared is consequently always being used up.

What is to be done with the remainder?

It must be put by, stored up somewhere for future use. Do you not remember the various storehouses we spoke of

when we were considering the duties of the full-grown plant? They are as varied and as interesting as are all Nature's plans and arrangements. There is no monotony with her.

Fig. II.



Root of *Œnanthe pimpinelloides.* Example of curious underground storerooms.

a, a. Two shrivelled-up tubers, the nourishment in which has been exhausted.

Dig up the pretty, starry, lesser celandine, which flowers so early in the spring, and look at its quaint, club-shaped, underground storehouse. Dig up a flowering purple orchis,

and remark its *two* storerooms. One is flabby and soft, almost empty; that is the one provided last year for this year's flowering season. The other is full and plump; that is the store for next year. Does it not almost seem as if the orchis were gifted with the power of thought and foresight? In many a fleshy stem, in the quaint thick leaves of the cactus, in root and root-stock, in thickened scales or swollen underground stem—in almost every part of plants, in short—we find the prepared food carefully stored away for future use.

I fear you must wait until our next lesson to hear what I can tell you about a few of the substances which are manufactured thus in the quiet "green factories," and either used up by the plant to supply its immediate needs, or stored away for its future requirements.

To-day I want to talk to you about a substance which cannot be said to be **manufactured** by the plant, but which the plant is always taking in and using—as it does water and other "raw materials," as we chose to call them—to make its food, by the "cooking process" we spoke of in the leaves.

Do not think, by-the-by, that because the plant can only take in liquids and gases, only liquid substances can be manufactured therefrom. Otherwise, whence would the plant obtain the solid portions of its body?

You must not be surprised at the manufacture of solid substance out of liquids. If you think and observe, you will soon see that a substance may change its form, and appear at one time as a solid, at another as a liquid, and again on a third occasion as a vapour. Think of *solid* ice, *liquid* water, and *invisible* steam. They are all the *same* thing under *different conditions.*

More than this; you will find that a substance may change its appearance under different conditions, so that you can hardly believe that the two appearances are really one and the same substance. A bit of clear, glassy ice is not much

like a handful of white, flaky snow, yet you are well aware that both will melt into water in your warm hand. This will help you to understand what I am going to tell you about the substance mentioned before, which is taken in by the plant in large quantities, and is the principal material for the building up of every part of the plant's body, including the strong woody trunks of trees.

The substance is called **carbon**, and it will be most familiar to you in the form of the coal which you burn in your fires at home, the greater part of which is made up of this substance.

"But the coal is black and hard, and the plant is soft and green and juicy; how can they look so different, and yet both have so much of the same substance?"

They do indeed look different, but you are prepared now to expect the same substance to look very different under different conditions. As to the juiciness of plants, however, contrasted with the hardness of coal, remember I did not say that the plants contained nothing but carbon! The juiciness will depend on the amount of water in the plant; the oak trunk and the tender green shoot it sends forth in spring are different enough in this respect.

But here is another surprise for you. You must all at some time have seen a beautiful sparkling diamond, perhaps set in a ring on a lady's finger, or in a brooch at her neck.

This clear, sparkling jewel is an example of carbon in its purest form, and is, therefore, a near connection of the black coal which you put on the fire! It is strange, certainly; but the sooner you can get accustomed to these changed appearances of matter, the better; for the nearer you will be to a right understanding of Mother Nature, and her wonderful and surprising ways.

But now we must consider whence the plant gets its store of carbon; whether through its roots, out of the ground; or

"Out of the ground," I hear you say, very confidently; "does not coal come out of the ground? and, besides, how could a solid thing like carbon come out of the air?"

But you are forgetting again. You know I told you that substances could take the form of solids, liquids, or gases, according to circumstances, and change from one to the other under varying conditions.

"Curiouser, and curiouser," as Alice in Wonderland remarks! But it is true, all the same, that the plant gets a great part of its carbon, though by no means all, out of the air, and takes it in through its leaves, in the form of a gas. This is called **carbonic acid gas**, and is a compound of carbon and of another substance called oxygen. It is to be found in all air, more or less, but more in towns, where there are crowds of human beings constantly breathing it out, than in open country places. For I must explain that this part of the air which is so necessary to plants is not at all good for human-beings. Every breath that comes out of your mouth is loaded with this unwholesome gas, some of which you had to draw in with the other parts of the air, but which your body cannot use, and casts out again. Some of the gas proceeding from your mouth is actually produced by certain processes going on in your body, which I will explain to you in a future lesson. This will help you to understand why a room which is shut up, so that fresh air from outside cannot get in anywhere, soon gets close and disagreeable, especially if there are many people in it. The good part of the air is gradually being breathed up, and the unwholesome carbonic acid gas increased in quantity; you cannot breathe freely, your head is hot and aching, and nothing will put you right but "a breath of fresh air," that is, of air which has not had all the good breathed out of it.

Now, this very part of the air which you cannot use is most valuable to plants, as we saw; and by using it up,

they purify the air for us! How wonderfully these things are balanced in Nature, are they not?

Then if you go to a big town some day, and see trees and bushes planted in the middle of it in squares, or avenues of trees along the streets, you may whisper lovingly and gratefully to the green leaves: "I know your kind work, dear leaves; I know that you are freshening up the air in this big city, for all the people who live and breathe in it; I know how you are taking in and using up the bad part which would injure them; I am so glad to see you here!"

But the kindly green leaves are doing something more for you besides their blessed, purifying work.

We spoke of coal just now, and said it was mostly composed of carbon, but do you know *how* coal is made? Not in man's noisy workshops certainly! We must go to Nature and her factories again. You all know that coal is dug out of pits; but long before Mother Earth took it down into her deep places, and pressed it under her heavy, crushing rocks, and treated it in various wonderful ways, until it became hard and black, and fit for our use as fuel, its substance was being made above ground, by millions of busy green leaves, by the help of the golden sunlight and the fresh air.

Too many ages ago for you to imagine, the work began. The earth was clothed with beautiful forests, wherein figured conspicuously numbers of tall, graceful tree-ferns, crossing their feathery fronds, one over another, till their shadows must have drawn patterns like lace-work underneath the straight stems. More ferns would be underneath, and a few other plants and trees, but there were few flowers in those green forests of long, long ago. Such forests, or something very like what they must have been, are still to be seen in New Zealand, on the other side of our globe, but you have seen nothing like them here.

What were those millions of green leaves doing, day by day, as they waved in the bright sunshine?

Just what leaves are doing now everywhere, all through the sunny summer days. They were taking in the air through their myriads of tiny "stomata," or little windows, as we called them, and extracting from it the carbon, which they needed to build up every part of their beautiful bodies; and all the while, though they little knew it, they were storing it up for you and me!

Years and years later those forests disappeared. Perhaps the land on which they stood sank down gradually, and the great sea came and swept over them. We do not know all that befell them in the slow course of ages, but they were certainly buried more and more deeply by the changes on the earth's surface; hard rocks formed above them, and they were pressed and crushed as if in a great vice. All their green colouring and delicate form was gone, the life was long ago pressed out of them; most of the gases and water of the plants had disappeared, but the greater part of the carbon they had stored up so unconsciously, all their busy, happy lives, was there, safely guarded for man in the depths of the earth, till he should come and dig out that black mass, and rejoice in the warmth given out by that substance, gathered from the sunny air so many ages before man was upon the earth at all.

This is the history of coal; and now you see that it is not surprising that the composition of coal should be like that of plants. So, with one more grateful thought for the kind leaves which purify our air, and at the same time turn the hurtful part they abstract into fuel for our use (for the wood you burn is also of course full of carbon), we must close our lesson for to-day.

SUGGESTION TO THE TEACHER.

The children may be requested to collect examples of storage-places of plants *above* the surface of the earth; such as fleshy fruits and stems, swellings beneath leaf-buds, the spadix of the cuckoo-pint, the receptacle of the globe-artichoke, etc. etc.

LESSON VI.

ASSIMILATION (concluded)—SUBSTANCES MADE IN THE GREEN FACTORIES.

We have talked much in our last two lessons about the substances taken in by plants, and the unwearying activity of the green leaves in preparing these "raw materials" and manufacturing out of them all that is required for the plant's daily growth and future needs. We peeped into some of the store-houses, and saw that they were full of nutriment; and perhaps it occurred to you to wonder if it would be pleasant to be asked to dinner by the plant, and supplied with food from its hospitable store!

I think the answer to that question must entirely depend on the plant which invited you. An invitation from some would mean nothing less than sudden death to you! From others you might safely accept hospitality. You see it will be wise to learn something of the nature and properties of different plants before tasting any part of them

Some of them are busy preparing substances which become most valuable medicines when properly and carefully used; but often these are deadly poisons if taken ignorantly and without precautions as to quantity, etc.

To chew the leaves of the foxglove or the purple monkshood would be exceedingly dangerous and very probably fatal, yet most valuable medicines are obtained from these two plants. Bitter quinine and bark, nasty rhubarb, castor oil (useful but not agreeable), senna for our "black draught," ipecacuanha for our coughs, laudanum to soothe our pain—

all these and many many more drugs have been prepared for us in those quiet "green factories" which we talked about in our last lesson, and stored away in various parts of the plant.

FIG. 12.

The castor-oil plant.

I am disposed to wonder if you, children, will feel as grateful for some of them as you should!

It would be a long business indeed if we were to make a list of all the substances which are to be found in different plants throughout the world. For the present we will leave

production? You have seen on the packet "best rice starch," do you say? Well remembered! Yes, we obtain our starch from the grain of rice, from the tubers of potatoes, and from different parts of other plants which happen to contain a large quantity of it; but you must not imagine that starch is *only* found in rice or potatoes. On the contrary, *almost every plant* contains it to some extent, though there may be more in one part of the plant than in another; and wherever you find a special store-house, in root, or stem, or leaf, or seed, you may be pretty sure that, amongst other substances, starch will be found therein. This, therefore, is a very important product of the "green factories," and is a valuable storage-food for the plant.

Is it of any use to us, besides stiffening our linen?

Oh, yes. "Starchy foods" form a large part of our diet. Bread for your breakfast and tea, potatoes for your dinner, cornflour, sago, rice, arrowroot, tapioca, beans, and peas—all these and many more articles of food contain large quantities of starch.

I will give you one practical piece of advice about these foods. *Eat them slowly.*

Why do I say this? Because the digestion of starch has to be done *in the mouth,* and cannot be properly performed in the stomach alone. There is something in the saliva in our mouths which acts upon the starch, and renders it fit to

be assimilated by our bodies. If, therefore, we swallow it without giving the saliva time to act upon it, we are very likely to suffer from indigestion, and the food is not likely to do us much good.

I said just now that starch was a valuable "storage-food" for plants. Why did I say that? Because it cannot be used by the plant just as it is. It is ready to store away; but when it is wanted it will have to be "digested" (just as you digest your food before you assimilate it), and in this process of digestion by the plant a new substance is made. The starch is converted into something which will appear to you very different indeed.

Before I tell you what that substance is, however, perhaps you would like to know of what starch is made.

Well, we have been able to find out that, though I think we must usually leave it to Nature to manufacture it for us.

There are three **elements** (or "raw materials") out of which it is composed.

The first is our old acquaintance, **carbon.** Are you surprised to meet it here again? You will find that it is wanted to make nearly all the substances prepared in the "green factories." You have not forgotten how it is obtained, I feel sure.

The other two elements are two gases called **oxygen** and **hydrogen,** which, together, make water. So starch is made of carbon and the two elements of water.

Now, when the stored-up food is wanted for immediate use—let us say, for example, in the germinating pea or bean —this is what happens: the starch in those fat leaves of the baby bean plant, which we talked about in our second lesson, is digested by the help of something in the juices of the little bean answering to that which acts upon starch, as I told you, in the saliva of human beings; it is changed and converted into another substance, which is even more familiar to

you, and perhaps more appreciated, than starch—namely, **sugar.**

It will surprise you, I think, to hear that the *elements* of sugar are *exactly the same* as those of starch, *only in different proportions.*

Sometimes you hear of fat people giving up sugar "because it is so fattening;" but if they eat quantities of bread and potatoes and other starchy foods, they need not expect to grow thinner, and they are likely to have all their self-denial for nothing!

You all know, I expect, what plants give us our principal supplies of sugar.

We English mostly depend on the sugar-cane from the West Indies and elsewhere. The thrifty French make theirs from beetroot, but it is neither so sweet nor so sparkling as ours. In America the children love maple-sugar, which is the sweet sap of the "sugar-maple" tree, drawn from the trunk in spring. Sweets and candies are made out of it in large quantities.

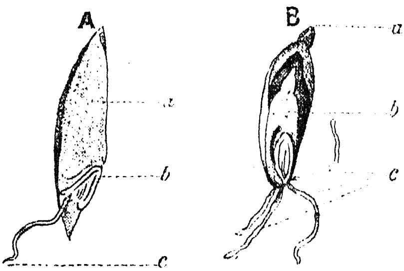
Sugar, the second production of the "green factories" which we have noticed so far, may then, from man's point of view, be described as a pleasant and useful article of food, fattening in its properties, but generally wholesome for children, and with qualities which make it extremely useful in preserving fruit and other articles of diet, and keeping them for a long period of time in a fit state for our use. Now, however, we must look at it from the point of view of the plant, and see of what use the sugar is to it, and *how and why* it prepares this substance.

There are several different kinds of sugar in plants, all made of the same elements, but not quite the same in proportions, and having rather different qualities. One of these, **glucose**, or **grape sugar**, gives the sweet taste to ripe fruit.

Does the plant put these pleasant sugars away in its storerooms, with the starch for future use?

Not as a general rule. Usually, when we find sugar in the plant, we may know that either the stored-up starch is being digested and turned into sugar, because the plant is going to use it up; or, on the other hand, the plant may be making starch, and may manufacture sugar as a first process, which sugar will presently be transformed into starch and stored away. Germinating seeds and sprouting tubers (the potato for instance) are nearly always more or less sweet. You can tell me why? Because the starch in them is being changed into sugar for the nourishment of the little plant.

FIG. 13.



A. Seed of germinating barley cut in half. Enlarged. *a*. Albumen. *b*. Acrospire. *c*. Rootlet.

B. Germinating barleycorn cut in half. The acrospire has grown right through the seed, and pierced the husk of the grain. The albumen is partly exhausted, and the process of germination has gone too far for malting purposes. *a*. Acrospire. *b*. Albumen partly used up by the growing plant. *c*. Rootlets.

We take advantage of this moment of the digestion of the starch and its conversion into sugar, to make malt, which, as you all know, is a necessary ingredient in the manufacture of beer.

Barley is the seed usually chosen, and the grains must be plump and healthy if good malt is to be procured. By a proper supply of heat, moisture, and air (which, I hope you remember, are the three requisites for germination), the barley is made to germinate. The tiny rootlets soon peep out and the plumule, or, as the maltsters call it, the **acrospire**, begins to grow inside the barley corn.

A careful watch is kept now, for the maltster knows that when the acrospire has grown about three-quarters of the distance through the seed, and would soon be putting its tiny nose out into the world, the moment has come to put an end to its little life.

All the starch is now converted into sugar. The barley is quickly dried on a hot floor; the poor little radicles dry up and drop off, and are separated from the "malted" grain, which is afterwards crushed and thus made ready for the brewer.

The sugar of malt is "glucose," or grape sugar, which, as I told you before, gives the sweet taste to fruit. Preparations of malt are often given to thin, delicate children, to fatten and strengthen them, and they generally think it a pleasant medicine on account of its sweetness.

We have talked so much about starch and sugar that we have but little time left to-day. Yet we must speak of one or two other productions of the "green factories."

Gum is a substance found in many plants. Curiously enough, it has the same elements, in the same proportions, as the sugar of the sugar-cane. Yet I fear you would not be contented with a lump of gum in your tea, instead of sugar. The reason of the difference must be a change in the arrangement of the ingredients. If any girl is learned in cooking, and knows what different results may be obtained by mixing the same materials in different ways, perhaps she will see how this may be.

Gum is found in many seeds (the mallow, for instance), and in the juices of some trees. You have surely often seen it oozing out of the stem or twigs of plum or cherry trees.

Like sugar, it is one of the substances made by plants in the course of the manufacture of their food.

I need hardly mention the ordinary uses to which we put it, though perhaps you do not know that several kinds of gum are much employed in medicine for various purposes.

Oil exists in very many plants, and especially in seeds, where it forms part of the store of food for the embryo. This is the case in the castor-oil bean, for instance, which

hazel nut, walnut, almond, and, indeed, almost all nuts are full of oil, which, however, in this case, is pleasant enough to our taste.

Olive oil, from the little plum-like fruit of the olive tree, is used by the French and Italians instead of butter, and we use it for making salads, etc.

The composition of the oils found in plants is a little different from that of the other substances we have mentioned, and indeed the different oils vary one from another in their ingredients.

There are very many other substances prepared in the "green factories" which we ought to mention, such as gutta-percha, or india-rubber, turpentine, tar and pitch, dyes of many colours, etc. etc., but we have not time to speak of them now.

Before we close, however, I want you to observe with me the threefold work of kindness done for us by the dear green leaves with the help of the blessed sunlight.

(1) Observe how plants *prepare* food for man out of earth, air, and water. Man could never do this for himself, but must perish with want were it not for the "vegetable world."

(2) Observe how plants *lay by* for man; storing away in root, grain, fruit, etc., the useful substances made by the green leaves, in such a manner that man is able to preserve them for use during the cold winter, when the plant world is more or less at rest from its labours.

(3) Observe how plants *purify* the air for us, taking in the part which is injurious to us, and transforming it into useful substances, which minister to our daily wants.

Let us never forget that, though our life is a far higher one than that of the vegetable world, yet God has made us completely dependent on those lower creatures of His for our very existence. A world without plants would be utterly uninhabitable; we could not live in it. So love these lower

fellow creatures with all your hearts, and especially the dear, busy, kind, green leaves!

SUGGESTION TO THE TEACHER.

Let the children make a list of all the substances they can think of, procured from plants. The lists should be written out if the children are old enough.

LESSON VII.

MOTION.

I DO not think you can have quite forgotten our first lesson, children, or our search after some signs by which we might decide whether a thing could be truly said to live or not.

We chose three signs of life:

1. GROWTH. 2. POWER OF ASSIMILATION. 3. MOTION.

I think we have now clearly seen that plants both grow and assimilate food. It remains to prove that they have some power of movement, independently of outside causes. Perhaps you think it will be hard to prove this? It is certainly true that movements in plants are not to be observed by every careless eye. Usually we shall have to watch both carefully and patiently if we would take note of their movements for ourselves.

We are so accustomed in the animal kingdom to regard motion as not merely a sign of life, but also of sensation and will, that I fear when you hear in this lesson of plants moving when touched, of tendrils searching for support, of leaves catching or closing on their prey, you will be disposed to say: "Then plants can feel, and have wills of their own, like animals!" But this conclusion, though perhaps it seems attractive and tempting, would, I fear, be quite a false one.

You know, in our first lesson, we remarked that there were two kinds of motion; movements made *with* the will of

the mover, and movements made *without* his will or control. The latter we called **reflex movements**. The action of our heart, lungs, etc. etc., are all examples of this kind of movement, and they proceed, as you know, even when we are entirely unconscious, in dreamless sleep.

All observations that have hitherto been made on the constitution of plants have taught us to feel certain that they can have no "sensation" according to our meaning of the word; although tracings of the **beginnings** of a nervous system like ours have been discerned in plants by some of our greatest observers in the scientific world; and they have been led to believe that some of the curious movements in plants of which I shall tell you, are caused by the same **unconscious** action of the nerves which causes the feet of a frog, lately decapitated (so that it cannot possibly feel or think), to move when tickled or slightly injured.

These, however, as I said before, are all reflex movements, whether produced by the beginnings of nerves like ours, or by various causes connected with their life and growth.

MOVEMENTS CONNECTED WITH GROWTH.

Do you ever grow sweet peas in your garden at home, I wonder, and put branching sticks for them to climb? If so, I feel sure you must have often wondered how the tip of the growing pea knew that there was a friendly stick at hand, ready to give it support, and managed to find it, even though it might be some inches away.

Perhaps you were tender-hearted, and took quite unnecessary trouble to guide the small pea-shoot to its support! It could have found the way very well by itself!

But *how?* that is the question. Well, you might almost think it had the consciousness of a little blind puppy, hunting for its mother with its small restless nose!

The "nose" of the baby pea-plant is never at rest, but moves ceaselessly round and round in a more or less wide circle, as if hunting for something. When it touches the stick, the same circling movement, aided by the sensitiveness to touch possessed by these and other parts of the plant, of which you shall hear later, causes it to curl round it and cling to it. These movements are too slow generally for you to observe with the eye; but it is very easy for you to prove them by experiment, thus. Sow a pea in a pot. Directly it begins to shoot up, take a round piece of white paper or card, as large as the top of the pot, and make a small hole in it, through which you must let the tiny shoot of the pea-plant grow.

When the plant is about three inches high, you will be able to make your observations.

Put the plant out of doors, where the light is equal all round it, and, with a pencil, mark on your card the point exactly underneath the tip of your little pea (it will almost certainly be bent slightly to one side or another). In an hour, or less, look at it again, and see if the shoot is where it was before. You will find it has moved; it has gone round, and the dot on the card is no longer underneath it.

Thus you may count its turns, and the time it takes for each!

The same kind of experiment may be tried with the top shoot of a young fir-tree; and the result will be the same. It moves; it goes round! But the tip of any climbing plant is by far the easiest thing for you to experiment with first, because the movements are so decided, and, comparatively speaking, rapid.

The young shoot of the hop is said to go round, on a warm summer day, at the rate of two hours and eight minutes for each complete turn. This revolving movement is not confined to the growing **shoots** of plants. As a matter of fact *all growing portions* of plants revolve slowly in this manner. The movement can be well seen in the radicles of

seedlings. It has been prettily shown by arranging the little plant with its radicle just touching a piece of smoked glass, when the tiny point of the growing rootlet traces its own corkscrew-like wrigglings clearly upon the glass as it moves.

What is the cause of these movements? you ask.

They are certainly connected with the rapid growth of these parts, and are supposed to be caused by the fact that the growth does not go on equally in all parts of the shoot or rootlet at the same time, so that one part is always outgrowing the rest, so to speak, and bending the tip of the shoot or rootlet, to which it belongs, accordingly.

There is no doubt that light has a great influence on the growing parts of a plant which are above ground, and their tendency is to bend towards it, because, as I told you before, light rather hinders growth, and so the part *not* exposed to the light grows faster than the other side of the stem. Light, however, naturally cannot influence the little root down in the dark earth, so its corkscrew movements must be caused by its own manner of growth.

SENSITIVENESS TO TOUCH.

But besides the wriggling movements of the little root (which, by the way, make it much easier for it to get through the soil than if it pierced straight down like a needle), it has other, more curious, powers, which would almost make us believe that it has some kind of beginning of a brain and sensation!

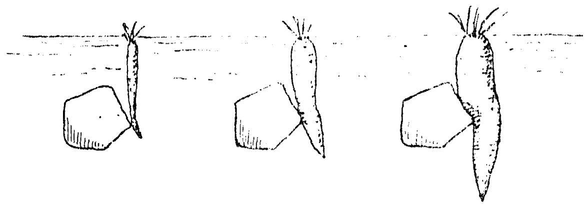
When the tip of the radicle (protected by that kind little cap which I described to you in an earlier lesson), meets a stone on its way down into the earth, how do you suppose it behaves?

"It cannot feel the stone," you say, "so what can the poor thing do but flatten its nose against it, and spoil its shape for life, at the best."

Nay, but it *does* feel, apparently, or it does something which answers the same purpose (for we must not allow that the plant has any conscious sensation). No sooner does it touch the stone than it turns away from the impediment and seeks a softer path, just as a mole or a worm would do if it came, in its burrowings, to a piece of rock.

That there is *actual sensitiveness*, of a kind, in the tip of the radicle has been proved by experiments with the

Fig. 14.



Growth of a carrot coming in contact with a stone in the soil. To illustrate (1) the sensitiveness of the tip of the radicle which causes it to turn away from the irritating body; (2) the sensitiveness of the root *above* the tip, which has the effect of causing it to bend *towards* the irritating body, and so curve round and preserve its downward direction.

radicles of seedlings, which, when slightly injured on on side, are found to turn away and bend in the opposit direction, as if to avoid being hurt.

But now suppose the point of the radicle of a carrot, fo instance, to have met with a stone, and avoided it by turnin to one side; as the growth proceeds and the root thicken its *upper* part is brought into contact with the stone, whic slightly scrapes it. Can this part of the root feel too, an will it bend still more to one side? for, if so, the carrot wi have to grow sideways, along the surface of the eart instead of downwards into the soil, where most food an moisture are to be found.

Perhaps the root knows this. At all events, when scrape or injured high up, above the tip, the effect is to make

curl round the obstacle, bending towards the thing which scrapes it, and so the root goes downwards as it should. But the carrot will not be a good shape, because the stone made it grow in a curve. So mind you dig your carrot beds well, and free them from stones.

The movements hitherto described can only be observed by a careful watching and experiment; but now I want to introduce you to a very "nervous" plant, which, when even lightly touched by your fingers, will shut its leaflets together, just as a frightened snail draws in its horns.

Your light footsteps would not shake the earth, but a horse galloping by will sometimes cause this delicate little plant to shut all its leaflets together as if in terror.

It is generally called "the sensitive plant" (*Mimosa pudica*), and you may perhaps see it in a greenhouse some day, for it is not a native of England. I am afraid if it did live here you would not give it much rest, for I am sure you would always be wanting to touch it and see it move.

It has a leaf shaped like what we usually call the "acacia" tree in our gardens, with two rows of little leaflets growing up a stalk, and it is these two rows which meet, leaflet to leaflet, like the palms of little hands pressed one to the other. When much irritated by touch or shake, the stalk on which they all grow also drops down towards the stem of the plant in a most curious way, as if the whole leaf had fainted.

There is another most curious plant with which I am sure you will sympathise. We may call it "the fidgety plant," (*Desmodium gyrans*, of the East Indies,) for it is never still.

It has a very funnily-shaped leaf, with a large leaflet at the end of the leaf-stalk, and two little ones on each side, lower down. It is the small leaflets which are so fidgety, as might be expected. They are never quiet, day or night, but seem to play together like two restless children. They

perhaps cross slightly; after a few moments they separate and jerk away from each other again; and so they go on continually, only they fidget more than ever when the weather is very warm and the air moist.

MOVEMENTS OF CARNIVOROUS PLANTS.

Neither the "sensitive" nor the "fidgety" plant can generally be observed by little English children, but now I will tell you of a curious native of your own country.

FIG. 15.

Drosera rotundifolia. (The sundew plant.)

This little flower lives in bogs or wet moors. If there is a nice peaty bog anywhere within your reach, you may go and hunt with a good hope of finding him at home.

There are three varieties of this plant; two with long, and one with round leaves, tufted like a daisy, and with some-

what a similar shape of leaf; but you may easily recognise any of them by the pretty rosy hairs which cover their leaves, and which frequently carry tiny drops like dew upon their points. Those rosy hairs are very pretty, and the dewy drops most enticing, so doubtless think the little flies and beetles that hover about them.

Let us watch a moment. See, one settles on a leaf. What has happened? Why does he struggle like that? Why does he not fly away?

Look at the pretty rosy hairs! They are bending over him; they are so sticky that he cannot free himself, and they clasp and hold him as in a trap. And now the edge of the leaf rolls up over its living prey, and it will open no more till it has sucked the juices of that poor little fly, and is ready to cast out his dry carcase. What is the meaning of this? Do plants eat insects? This is indeed turning the tables on the insects who generally have it all their own way with the poor vegetables.

Yes; these curious little sundews (*Drosera*) are members of a party of insect-eaters among plants, which are certainly an exception to the general rule. There are foreign members of this group which move quicker, and are, perhaps, even more interesting to watch than the sundews, but I chose the latter because I hope you may see them yourself some day. I once kept a number as "pets," and fed them with raw meat and various kinds of food, and tried many experiments with them, some of which were most interesting. These plants **digest** their prey by a kind of juice which they pour over it from their rosy hairs, very much like that in our stomachs which performs the same office for us. I found that an over-supply of meat brought on an indigestion, from which it was possible for the leaf to die. Even plants must be temperate in their eating, you perceive.

Now, if you try the experiments and make the observations

plants do really "move of themselves." There are very many other movements in plants of which I should like to speak, but our time is too short. You must look for yourselves. I have not even mentioned the so-called "sleep of plants"; an effect of the absence of light which causes many flowers and leaves to close at night.

It would be death to many a little seedling to keep its two

FIG. 16.

a. Oxalis leaf and flower in the ordinary position.
b. Oxalis leaves "sleeping."

leaves open and apart at night, on account of the chilling they would undergo from what is called "radiation."

Look round your gardens after the sun is down, and see which of the leaves and flowers feel the influence of night. Notice the leaf of the wood-sorrel in the bank, the common clover in the meadow, the flower of the wee scarlet pimpernel by the roadside.

See when the heavy clouds come up during the day-time how many flowers close hastily, lest their stamens and pistils

during a shower! Half an hour ago they were sunning themselves with every petal wide!

Again, see the big sun-flowers turn their heads to the sun. Plant them out with their backs to him if you will, but they will twist round and look at him, for all that!

You will learn more by observing for yourself than I could teach you in many lessons. I can only hope that in these talks of ours your interest has been so awakened, and your sympathies so drawn out towards these "lower fellow creatures of ours," as we love to call them, that you will make of them and of Nature friends for life; believe me, dear children, you will hardly find better ones, nor any who will lead you more surely and sweetly, if you will let them, to their Father and yours—even the God of Nature.

SUGGESTION TO THE TEACHER.

Let the children make lists of all the flowers and leaves (or collect and dry them) which they find closed at night. Also of flowers which close in cloudy weather.

PART II.

NOTE. *The subjects of Part II. of this little book do not admit of being put in quite so simple a form as those of Part I., consequently they are adapted for rather older children than some who might be capable of entering into the earlier lessons.*

LESSON VIII.

THE CONSTITUTION AND CONSTRUCTION OF THE PLANT.

MY little pupils and friends who have gone with me through the earlier lessons in this book, and been really interested in those "lower fellow creatures" of which I have written, and in their works for us, will, I hope and think, care to go a little more fully into the subject, to dip beneath the surface, and to fill up much that we could only outline, as it were, in those first lessons. You will like to hear how the plant is made, how it looks under the microscope, and in what measure it is like our own bodies. And this is what I hope to explain to you in our lesson to-day.

Now, with regard to the word "body," you must understand that it does not by any means necessarily imply flesh and blood, like that of animals and men. The body of any living thing is simply the substance which has been gradually absorbed (or taken in), and assimilated (or made like itself), by the living germ with which that being began. It is that material which life of any kind has gathered to itself and formed into a shape of its own, to fulfil its needs, and by which it makes itself known to you.

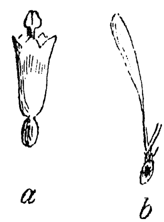
You cannot touch the actual life of a plant, but you can see and touch its green leaves, you can smell its flowers, and taste its fruit. Leaves, flowers, fruit, root, and stem—all these are parts of the body of the plant.

Now look at your own bodies. Hands and feet, head and

FIG. 17.

The daisy's "green body."

FIG. 18.



The little florets that dwell within the "green nest." Magnified.

shoulders, eyes and ears, they are all, in this sense, parts of our body; they are the substance which the life within us has absorbed and assimilated, and then formed into these wonderful instruments for carrying on all the complicated work of this living machine which we call our body.

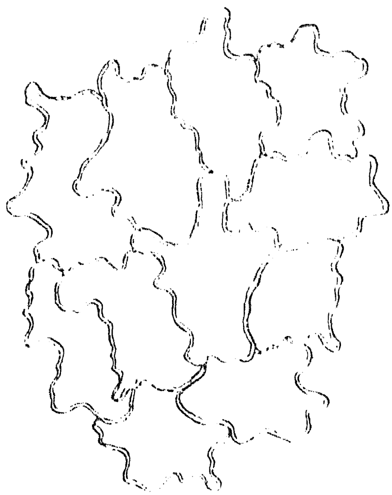
Think of those two ladders of life that we spoke of in a former lesson, and of all the various forms of life we saw upon them.

Each one had *its own* body, fitted for its *special* needs and purposes.

In S. Paul's words: "God giveth it a body as it hath pleased Him, and to every seed his own body" (1 *Cor.* xv. 38).

Here is a little common daisy, dug up by the roots. Let us look at its small but perfect body.

FIG. 10.



Cells from a daisy's leaf (the "crinkled network"). *Seen though the microscope.*

Those slender white fibrous roots are the food-seekers. Follow them up and we come to a thickened stem, partly underground; this is the **root-stock**, and is the daisy's principal storehouse.

Out of it spring little tufts or bunches of green leaves. You have not forgotten the "green factories" where the food is prepared, nor the little windows in them where the vapours and gases are taken in as "raw material" to be used in the course of the manufacturing business. Out of the little tuft of leaves rises a slender stem which supports a pretty green cup. Dainty pink-tipped petals and the yellow "eye" make up what you call the daisy flower, only really it is a number of tiny, little flowers all living together inside the cup, like birds in a green nest.

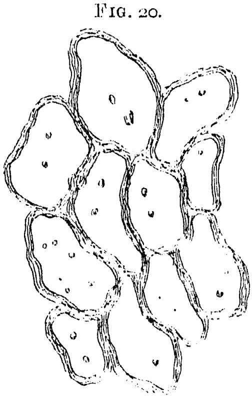
These parts together make up the body of the daisy; and you think it so different a body from your own, that you cannot imagine that the two have anything in common. Do not let us be too hasty, however!

I take a morsel of the daisy's green leaf and put it under

my microscope. What do I see? Something like an irregular kind of network, dividing up all the substance of the leaf into numbers of little chambers of rather uncertain shape and size. I take the thinnest possible slice from the root-stock, or from the white root, and examine it, and find the same kind of network, though the little chambers may be smaller or of different shape, and the walls that surround them may be thicker.

Now what is this network? You have seen a honeycomb, have you not? and you know that the little chambers or **cells** of which it is composed are made of wax, and each little cell is full of liquid honey. If you cut a slice through a honeycomb it would look very much like this network in my microscope, would it not? though the shape of the cells would be rather more regular than these. In fact, this net-work, which the microscope shows us, is entirely composed of **cells,** such as those of the honeycomb, separated from each other by walls more or less thick, and containing—but stop! we must not speak of the contents just yet.

FIG. 20.



Some thicker-walled cells from a daisy with *nuclei* (the "busy spots"). *Seen through the microscope.*

Every part of the little daisy's body is built up of these tiny cells, from the point of its pink-tipped petal to the tip of its white root. I do not say they are all alike; we shall hear more about their varying shape and their different walls later on; but every bit of the daisy's body is composed of cells of one kind or another.

Is the daisy peculiar in this?

No, indeed! Every living plant is built up in the same

go to form the substance of every living body are mainly built up of tiny cells. Your own body is full of them, and the amount of work which is accomplished in these minute chambers would astonish you indeed!

So far, your body and that of a daisy are composed after somewhat the same plan, each being built up of little cells; but we shall note some differences presently.

The whole body of the daisy is entirely made up of separate cells, which have *no doors*, and no communication with the neighbouring cells, *except through the walls*.

Every tiny chamber is surrounded by other similar chambers; there are sometimes irregular spaces between the cells, so that they do not quite touch each other, or only partly so; but there are no regular passages, as there are in a house, leading from room to room; and, as I said before, no doors to the little chambers! A house planned like this would be an awkward sort of place to live in, would it not? How would the inmates of each little room get food and the necessaries of life? Before we explain this difficulty, let us take a glance round our own body, and see how matters are managed there.

It is, however, perhaps rather a large mansion to go over in a single morning, so let us choose one department for our inspection. We will take one of our largest and most useful organs, namely, the liver.

It does many important works, but our business is not with its works, but with its construction; so let us observe it from this point of view.

Here are multitudes of tiny cells clustered together, just as in the daisy's body; but, running amongst these little chambers, there are numbers of small passages. These passages are of two kinds, I notice: one set is employed solely to carry away the juices which have been manufactured in those busy chambers. This set of passages is a peculiar arrangement belonging to the liver and some of our other organs, whose

business it is to manufacture juices and send them away to other parts of the body; so we will set them aside. But the second set of passages is common to every part of our body; none is without them. Their business is to carry the blood to every cell, in order that the cell may absorb from it whatever is necessary for its own nourishment and for the production of its own special manufacture, whatever that may be.

"Ah, this house is better arranged than the daisy's," you say; "we can't think how the daisy cells can get on at all without passages to bring their food to them."

Well, though the difficulty may be lessened, perhaps, in the human mansion, it is not done away with; for, although the food is certainly brought by the passages to the cells, *there is no door* in the cells through which it can be received. So here we are in much the same dilemma as before.

"Then the only way is *through* the walls!" and I see you look at the solid walls of this room, with a despairing hopelessness as to the possibility of procuring bread and butter or roast beef, if it had to be spirited through them before you could get it. However, matters are not quite so bad as that, and the inmates of the cells have more chance of a dinner than would appear at first sight.

The walls of the cells, you must know, are only composed of thin membrane, or a delicate kind of skin, and the food (as you remember I told you before with regard to plants) is entirely liquid.

You shall hear more about the manner of its entering the cells later. I will only explain now that every atom of nourishment supplied to the cells of either plants or animals has to *pass through* these delicate walls; you will see, therefore, that *no solid matter* can possibly be admitted.

But I see you are a little puzzled, and it is natural that you should want to know what happens to the solid food which you take into your own body every day for its nourishment.

Not a particle of it can enter into the blood-vessels and

mix with our blood until it has been completely melted up. You and I can no more take solid food into the cells of our body than the daisy can; only you and I have a wonderful and complicated arrangement inside us for melting up all the nourishing and useful parts of the food we take, the useless remainder being afterwards got rid of.

We are not learning now about our own bodies, and, interesting as the science of physiology is, we must not do more than dip into it just sufficiently to show something of the differences between our bodies and those of plants; but I must just explain shortly that the food passes from the mouth to the stomach; after that it is acted upon in various ways by different organs and juices of the body, until all that is useful for food has been melted up and made liquid. The liquid food passes into the blood-vessels by much the same process as that by which the blood itself passes into the closed cells to nourish them.

CELL CONTENTS.

By this time I think you are feeling a curiosity to enter those closed and doorless* cells, and to see what there is inside, which, as I have hinted already, works so busily and silently.

You remember we took the honeycomb for our type of **cellular tissue,** as we call this network of cells.

Every waxen chamber therein is filled with clear liquid honey; and this is not a bad representation of the contents of the daisy's cells, which consist principally of a jelly-like substance, more or less fluid and colourless, called **proto plasm.** A wonderful jelly indeed is this, for no kind of life whatever is known to begin without the peculiar combination of materials which goes to make it up. In this jelly-like protoplasm all life takes its start.

* Although we may fairly describe the cell-walls as "doorless," yet in some cases they are certainly pierced by thin threads of protoplasm, by means of which a direct communication from cell to cell is established.

Do you remember how, at the bottom of the two "scales of being," we found both animals and plants which were like little lumps of jelly? Well, they were, in fact, little more than masses of protoplasm, with the germs of a low form of life working in them. And if we pass all up the scale of being and come to its crowning point, the human body, what do we find? It is a marvellous and wonderful building, this body of ours, but it is all made out of the same materials as the jelly-like creature at the bottom of the scale. Yes, it is all originally developed from a speck of animal protoplasm,* which has been worked upon, has been made to assimilate fresh matter, and, finally, has been formed into this beautiful and perfect structure by the unseen, God-given life within!

Does it make you feel humbled to think that your body is made of exactly the same elements as that of the daisy or the jelly-fish? Nay, you may rather feel a kindly sense of relationship to all your lower fellow creatures in Nature, and be thankful for the higher life in you, which (just as the spirit within you gives expression to your faces, making them show forth its qualities) has given this wonderful form and expression to the common material which a lower kind of life only forms into a vegetable, or into a senseless jelly-fish. But let us return to the cells of the daisy.

I spoke of the busy activity of the occupants, did I not? Life is hard at work amongst the little lumps of protoplasm, doing many wonderful things. Remember all that was said of the "green factories" and their works; all these things are done *within the cells.*

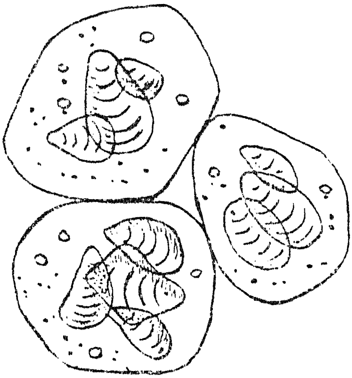
In many cells we may observe, within the mass of protoplasm, one or more darker spots. These *nuclei*, as they are called, are like little centres where the work is most vigorous; they are the busiest spots of all.

In the jelly-like substance of the protoplasm, many other substances are gradually formed.

* Usually called sarcode.

In the leaf-cells little green particles are to be seen (under the microscope), which are the colouring matter of the green leaf; and very important little atoms they are, as you shall hear another day. In some cells little grains of starch are found; in others, tiny drops of oil; but we must leave out of consideration for the present all these other substances formed by the protoplasm, and come to the question: **What is protoplasm?**

FIG. 21.



Cells from potato containing starch granules. Very much magnified.

An important question like this, however, cannot be answered in a word.

You have taken in (and, I hope, assimilated) enough knowledge for one day, and we will wait till our next lesson to discuss fully this wonderful "basis of life," as protoplasm is often scientifically described.

SUGGESTION TO THE TEACHER.

Let each child choose an animal and a plant, and give as complete and clear an account as he is able, of the outward form of the "body" of each; mentioning the uses of each part, as far as he knows them.

LESSON IX.

PROTOPLASM AND ITS ELEMENTS.

What is protoplasm? That is to be our question for to-day, children.

Outwardly, as I told you before, it resembles a sticky, colourless, more or less fluid jelly; yet in this slimy, unpromising looking substance, that wonderful mystery, which we call **Life,** first began to show itself. The word "protoplasm" comes from two Greek words: *protos*, "first," and *plasma*, "formative matter," and this name is given because in this mysterious jelly-like substance, life *first begins* its work of forming or building up the bodies of living creatures. Life, and the combination of elements called "protoplasm," seem so mysteriously connected that where this particular substance is formed—there is life.

Here, it seems to me, it might be well to try to explain to you clearly what is meant by an **element.** In our first set of lessons I spoke of the "raw materials" taken in by the plant, and "cooked," or prepared, for its own use. Afterwards, instead of the expression "raw materials," I used the word "element." You understand, therefore, that the elements of a thing are the materials out of which it is made. The word means more than this, however.

If I said: "the elements of sugar are carbon and water," I should not be speaking correctly, because water is composed, or **made up,** of two gases; but if I said: "the elements of sugar are carbon, oxygen, and hydrogen,"

mixtures. Each of them, however carefully we analyse it, is found to be *one and the same all through.* This is what is meant by an element; something which is *not a mixture,* and which we *cannot separate into two or more* different materials.

Do we know what the elements are of which protoplasm is composed, and can we make it, and bring a living being into existence? We do know its elements indeed; our men of science have been able to analyse it and to tell us this, and you shall hear the results of their investigation presently. But the mysteries of life are not given into our keeping; not the simplest of living beings can be brought into existence by man. He has never yet succeeded in imitating protoplasm, well as he knows its elements; and how it was first formed neither I nor any man can tell you. That peculiar combination of elements in which life always manifests itself seems sacred, and its secret is with God alone.

But we will come to what we do know, for you are longing to hear out of what materials your bodies and mine, and those of every living plant and animal are built up.

The *first* is quite an old friend of ours by this time. I told you that we should meet it often, and that you would have to learn to recognise it under many different forms.

I think you have guessed that I am speaking of **carbon.** I told you that the principal part of the solid substance of plants consisted of carbon, and indeed your own bodies contain, and are constantly taking in as food, a large proportion of this element.

Good charcoal consists of carbon in almost a pure state, but the purest form that we know of, as I told you before, is the diamond.

If carbon is one of the elements out of which our bodies

)o you remember that I explained to you (at the end Lesson VI.) our dependent nature as regards our food? elements of our bodies are indeed all around us, in earth, air, and water, but we are helpless to prepare n for ourselves in such a manner that we can assimilate m. The kind vegetable world must do this for us. Further l, it is only certain plants that produce exactly the right ıbinations for our food.

Iow particular our bodies are about the exact propor- ıs and arrangement of the elements that nourish them, they not? But the plant world is particular, too, in its y, and if you offered a diamond to your favourite geranium vould be much puzzled how to assimilate it. So, remember, elements of life are all around us, but it is only under tain conditions and circumstances that they can become d for living beings.

Let us pass now to the *second* element of protoplasm. You do not know it by sight, as you do carbon, for it invisible; nor do you know it by taste or smell, for it s neither; nor can you feel it, though it is all around u now. Yet you depend on it every moment for your istence.

That sounds a strange riddle, yet perhaps you understand e, and know that I am speaking of the **oxygen** in the r.

This invisible gas is what I called "the good part of the r" in a former lesson. I described it so, because it is the ırt of the air which is necessary to sustain our life. This it)es by a process which I can best describe as the **burning** the blood and tissues of our body to produce the vital heat ıd force.

This sounds very alarming perhaps, but it is really only ıe same thing that I said to you in our very first lesson, hen I spoke of the constant "dying" of little particles of ur body, and the consequent need of replacing them by new

substance. In another lesson I will try to explain the matter more fully to you, but we will not interrupt our description of the elements of protoplasm to go into it now. It is enough for the present that you understand that the oxygen in the air is that part of the atmosphere which is necessary to maintain your life.

Though in its pure state oxygen is an invisible gas, it is very willing, under suitable circumstances, to enter into combination with other elements; and when thus combined it takes many forms, and is said to compose one half of the crust of the earth (that is the outer layer of our globe, as deep as we have been able to examine it).

That is rather a startling assertion, is it not? for the earth looks very solid, and not at all as if it contained so large a proportion of an invisible gas! But then, you know, we resolved to keep in memory the fact that solids, liquids, and gases are only substance under **different conditions**, and that the same substance may appear in one state or the other according to its circumstances.

In the earth we see oxygen, combined with other elements, in a solid form; now I will show it to you as a liquid. But wait! It is time to introduce the *third* element of protoplasm.

This is called **hydrogen**, and is another invisible, tasteless, odourless gas. Combine it in certain proportions with oxygen, and a liquid is formed. What is it? Pure water. Perhaps you remember that I have mentioned the elements of water before as oxygen and hydrogen.

This third element, hydrogen, is not found in nature pure, and free from any other substance, and the only way in which you are likely to be on familiar terms with it is when combined with oxygen as water. I hope you are very fond of it in that form, and that it is a really intimate acquaintance of yours!

of water! they do not seem very promising materials out of which to build the wonderful human body and all other living bodies! Let us come to the *fourth* element.

Nitrogen is another invisible, tasteless, colourless gas! It is plentiful enough, for it forms four-fifths of the air we breathe.

We need it to repair and renew the tissues of our body, and without it we must inevitably waste away and die.

"Well," you say, "there is no need for such a melancholy end, if the air is full of it! we should be like a man dying of starvation at a full table!"

The nitrogen in the air, however, is not in a suitable condition to be assimilated either by plants or animals. The only useful purpose it seems to serve thus is to *dilute* the oxygen which, by itself, we could not breathe. It does not mix or *combine* with the oxygen in the air under ordinary circumstances, though in tropical countries where there are very violent thunderstorms it sometimes does so combine, and then (or whenever oxygen and nitrogen and hydrogen are made to combine) a substance called **nitric acid** is produced. In this form, or when the nitric acid is further combined with potash and becomes **saltpetre**, the nitrogen becomes fit for the use of plants. But probably the form in which they generally obtain their nitrogen is as **ammonia**. This is nitrogen combined with hydrogen.

I dare say you have, some of you, on one occasion or another, smelt a bottle of "smelling salts"; and, if you took a good sniff the first time, perhaps you were a little startled at the stinging, pungent odour, which quickly brought the tears to your eyes! These salts are almost entirely made of ammonia, and it is this which gives them their irritating, pungent smell.

Sal volatile is another mixture, containing ammonia, with which you are likely to be acquainted.

Ammonia is constantly being given out in various forms

by all animal bodies; our perspiration, for instance, contains a small quantity of it. The decay of any animal substance always produces ammonia; so the atmosphere and soil are constantly receiving it from one source or another. Carbon has the property of absorbing this substance. The carbon in the soil, of which there is always more or less, takes it in and keeps it for the use of plants; and in this combination it suits them remarkably well.

Ammonia also mixes easily with water, and the rain often conveys it thus to the roots of plants.

Of course it is, as usual, through the plants that animals get the supply of nitrogen which is so very necessary to them for the repairing and renewing of their tissues. Some vegetables—peas and beans, for instance—contain very much more nitrogen than others; they are therefore more nourishing, and are much used by vegetarians. But we human beings mostly "take a short cut" to get our nitrogen, and obtain it by eating meat, eggs, and other animal food, which contain a large amount of it in a small space.

Now we have spoken of four elements; carbon, oxygen, hydrogen, and nitrogen. When we have added to these a very small quantity of **sulphur** and **phosphorus** we shall have the elements of protoplasm complete. Probably you know sulphur in the form of a yellow powder, sometimes used in medicine. It is often burned to stupefy bees when the honey is to be taken, and its fumes are also employed to disinfect rooms where fever has been.

Phosphorus, which we use, as perhaps you know, in the manufacture of lucifer matches, and also in medicine, is not found in a pure state in Nature, but always in combination with other substances. It is contained in the bones of all animals.

Both sulphur and phosphorus are produced in certain forms and combinations, when any animal matter decays; and the plant absorbs them by its roots, with the water which

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These, then, are the elements of protoplasm; these, with ome other less important substances, are the contents of hose myriads of tiny cells which compose the mass of all rganisms, from the shapeless lump of jelly at the bottom of he scale of life, to the wonderful human body. A little arth, a little air, a little water. How true it is that "dust ve are, and unto dust shall we return."

"It is the Spirit that quickeneth"—the marvellous God-iven life within us has united and **organised** these common lements, and formed out of them this mysterious structure *hich feels, and thinks, and can wonder at its own perfections.*

Possibly this lesson may have seemed a little dry and diffi-ult to you. But I think we could not hope to even *begin* to nderstand the constitution or the structure of plants without eing able to form some notion of the elements which com-ose them; and I hope that the pleasure of watching the lants at their daily work, and understanding a little of what hey are doing, will repay you for any efforts you may have nade to-day.

Let us glance back for a few moments, before we close, and nake it clear to ourselves whence the plants obtain each of e necessary elements.

(1) **Carbon** by the leaves, out of the air, in the form of carbonic acid gas, a combination of oxygen and carbon, as explained in Lesson V. The leaves separate these two elements, keeping the carbon for their own use, and setting free the oxygen, which is so necessary for our life. Thus they "purify" the air for us. Carbon is also taken in by the roots, from the soil, as carbonic acid (again com-bined with oxygen) dissolved in water.

(2) **Oxygen** is taken in with

(3) **Hydrogen**, as water, by the roots, and as vapour by the leaves. Under certain circumstances some pure oxygen is taken in from the air by the leaves, and more especially by the **flowers** of plants.

(4) **Nitrogen** by the roots, combined with hydrogen as ammonia, and in some other combinations.

(5) **Sulphur and Phosphorus** by the roots, in various combinations with other substances. They are especially found in suitable form for absorption by the plant where the decay of animal matter is going on.

SUGGESTIONS TO THE TEACHER.

In order to study the results of different combinations of elements, let the children try how many different tints they can produce with the three cardinal colours, red, blue, and yellow.

In the case of girls possessing some knowledge of cooking, the subject might be studied by each taking a given quantity of three or more ingredients (say sugar, butter, and egg) and cooking them according to a different plan of combination; the results being produced afterwards for comparison.

LESSON X.

CELLS AND VESSELS. THEIR GROWTH AND DEVELOPMENT.

We were out in the wide world in our last lesson, children, hunting for the elements out of which the bodies of plants and animals are built.

To-day, however, I propose to confine ourselves to a narrower space.

Let us enter again in spirit, as we have done before, into the body of the daisy, and examine more closely into the structure of those minute cells of which every part of it is composed.

Of the protoplasm which these cells contain we have spoken pretty fully, and possibly you remember my allusion to the little green particles embedded in it, which form the colouring matter of the leaf, and which I said were very important little atoms indeed. These two—the protoplasm and the green atoms, called **chlorophyll**—are the busy workers within the closed cells, by whom all the life of the plant is carried on.

In the centre of the cell, within the protoplasm, we shall generally find little spaces, called **vacuoles**, filled with cell-sap, that is with fluid (containing various substances in solution) which has been taken up by the roots. This is the "raw material" for the use of those busy workers.

Let us now examine these doorless walls which shut them in, and see how, and of what they are made.

The material is called **cellulose**, and it is composed of

three of the elements of protoplasm, namely carbon, oxygen, and hydrogen.

These are also the elements of sugar and starch, and even the **proportions** are the same as in the case of starch, so (as we said once before when speaking of gum and sugar, which have the same elements in the same proportions) the only difference can be in the mixing.

You will notice that nitrogen, which forms such an important element in the protoplasm, is not to be found in the cell-walls which enclose it. These walls do no work except that of protecting the working material within them; they are less alive than their contents, which is a strange thought, when you consider that they are actually portions of the same living organism. But it is a fact that, not only in the vegetable but also in the animal world, each individual plant or animal is made up of numbers of little working, living, separate atoms, each with its own little piece of work to do for the general body; and this general body depends for its comfort and health upon the manner in which each of the wee atoms does its duty. The body is really a multitude in one.

We may carry that thought on, if we like, and look upon ourselves as tiny, separate cells in the great body of humanity, and remember that the right doing of our work is of real importance to that body, just as it matters to our little daisy whether the wee cells of its leaves are working properly and doing their duty or not.

But to return to the walls. "How were they built"? you ask.

Let us go to the very bottom * of the scale of life and see for ourselves.

Here, on the animal side, we see shapeless specks of slime which are nothing more than little lumps of **animal proto-**

* Reference to embryology appearing unsuitable in a work intended for children, it has been necessary to take all illustrations of the process of development or evolution from existing forms of life of the lowest types.

plasm * as we may call it. In fact, they are like the contents of a single cell, without any protecting walls at all. On the vegetable side, the specks of jelly which form the lowest plants have made already a faint attempt to provide themselves with a covering and protecting membrane. The outside of them † is firmer and stickier than the inside; in fact, the protoplasm is at work making itself a house.

It is the nature of plant life to develop in this way, separating off each little cell from its neighbour by walls, which, as we shall see, often become very thick and firm indeed.

The animal life develops somewhat differently. The cell membranes have not quite the same chemical composition, and they do not, as a rule, become thick and firm as in the vegetable.

A little higher up in the scale of vegetable life we find that the protoplasm, after forming a thicker layer on its outside, as we saw before, has now begun to build firm, enclosing walls. As we go higher up the scale of vegetable life, these walls become more distinct and firm.

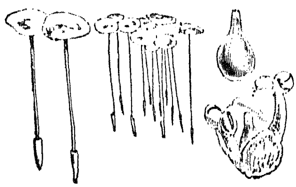
Finally, we arrive at plants like our little daisy, which is built up of a number of *separate*, individual cells, each surrounded by its wall, each doing its *own* work, but, as we shall see, *not* by any means each *the same* work that its neighbours do.

You may have thought, hitherto, that all the cells of our daisy were the same in shape, had the same thickness of walls, and did the same work. But this is not so. Apparently our daisy has got beyond thinking that every one should be equal, and that the world would be happier if every man were exactly like his brother man. At the bottom of the scale of life, down amongst the little lumps of jelly, it was so. There, in those lowest forms of plant-life, each cell (if there were more than one; for some of these wee, simple plants can boast but

of a single cell, like a one-roomed cottage, wherein all the work of life must go on) each cell is exactly like its neighbour, and each cell "does everything"—it absorbs and assimilates food, it grows, and can produce other cells like itself. It does not depend on other cells for anything, and if it be separated from them, it really does not mind a bit, but sets up house for itself quite happily!

In these very low forms of vegetable life, any bit cut off from a plant will live and grow, because each cell is really complete in itself, and independent of the others. Now that may seem very attractive; but if we are to follow Nature and her teachings, it is not the highest and best ideal to set before oneself. For which of you can doubt that the beautiful beech-trees of our woods, the violets and roses of our gardens, or this little daisy we are examining, have a higher kind of life than that of the green slime growing on wet stones, or even the "duckweed" in a stagnant pond?

Fig. 22.



Lemna minor (Lesser Duckweed). The flowers come on the margins of the leaves. To the right is a magnified flower which can set seed, though it has no bright petals.

The duckweed, however, has begun to set the cells of its body to different works. Some of them make up the little white roots which hang down in the water, and it is their business to *absorb the nourishment* for the tiny plant. Then the cells of the small green leaves must "cook" or *prepare it*, whilst those of the minute and very inconspicuous flowers must do their several parts to *produce the seed*.

We are ready now to glance at one or two different kinds of cells which, amongst the higher plants, have been set to special work.

The lowest forms of life, both animal and vegetable, are mostly to be found in water, where they are saved the trouble

of supporting their own weight, and float about lazily without a bone of any sort (much less a **backbone,** which is always getting into a rounded position, and causing its possessor to be scolded and desired to "sit up")!

The green inhabitants of the earth, however, when once they have begun to aspire to rise above the brown soil and enjoy a bath of sun and air, must be provided with something stiffer in their composition than thin walled cells.

Did you ever see a bouquet of "skeleton leaves"?

They are leaves from which all the soft, green substance has been removed by some process, and only the white network of so-called "veins" is left. Very pretty and lacelike is the delicate tracery of this fine network. But what is it?

The very word "skeleton" may help us to the right view of its nature, for it represents our **bones** rather than our **veins.** It is that which gives firmness and stiffness to the surrounding tissue, and without such a provision of "ribs" or "bones" the leaf would be very limp and exceedingly liable to get torn and injured.

Look at the firm, strong stalks of plants. They are evidently of the same nature.

Now look at the woody stem of a lilac, and then at the great, strong trunk of an oak or beech.

What sort of cells compose the network of the leaf, the stalk of a flower, the stem of a shrub, or the trunk of a tree, do you suppose?

Let us see.

In the cells forming the soft, green part of the daisy-leaf the protoplasm has been contented to surround itself with thin, delicate walls, through which the sunlight and air, required for its manufacturing work, might easily penetrate. But in many cases, where a firmer substance is required, fresh layers are repeatedly added by the protoplasm to the walls of the cells, until they become sometimes so thick as to leave hardly any space inside the cell. The shells of nuts and the

stones of cherries are made of such cells as these, and many tough and leathery leaves have thickened cell-walls.

We must remark, however, that, as a rule, these layers of thickening material are not deposited in an unbroken circle all round the cell, but in such a way as to leave tiny passages open to the old cell-wall.

These passages are so arranged as to have their ends exactly opposite to the passages of the next cell, only the original thin cell-wall coming between. Thus, you see, there is still a possibility of some sort of communication between next door neighbours, which would hardly be the case if they had to carry it on through those terribly thick walls!

The form of a cell which is not pressed upon and can grow comfortably, is usually more or less that of a circle or an oval, but the pressure of other growing cells around it, and various other circumstances in its development, may cause it to take many different shapes.

The cells of the green tissue from our daisy's leaf were like an irregular crinkled network; others will take more regular forms, often resembling crystals.

Now, if I examine through my microscope a particle from the mid-rib of a leaf, I find that the shape of the cells which compose it is totally different from the more or less rounde forms we have looked at hitherto. They are long an narrow, and they taper to a point at each end, so that the fit together like spliced sticks. Their walls are thickened b a **woody** deposit, which has been laid upon them by th protoplasm.

You can easily see how very strong a substance forme of such cells can become. In fact, this is the "wood matter" which composes the principal part of the trunks c trees. The stringy part of the stalks of flax and hemp also made up of long, thick-walled cells like these, and th is the secret of their toughness and strength.

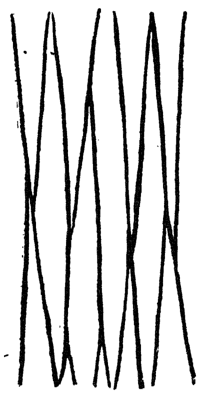
Amongst such woody tissue we may often find anoth

structure of a tubular shape which I must now describe to you.

The common plantain growing by the wayside will furnish us with an example of what we want.

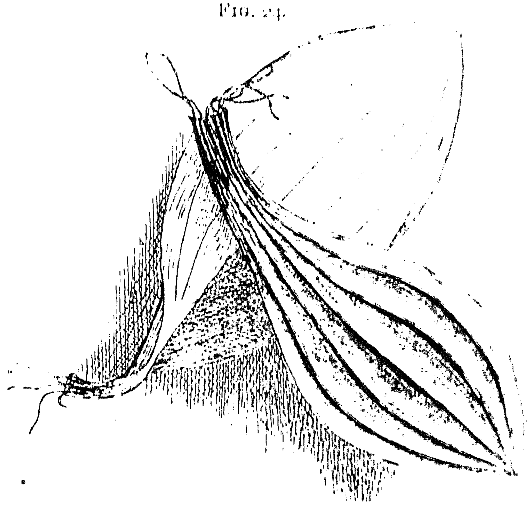
Gather the largest leaf you can find. You will notice some little green threads in the stalk, which you can very easily pull out, and which leave little holes where they have been. If we boil these threads it will make them very much

FIG. 23.



Wood cells.
Greatly magnified.

FIG. 24.



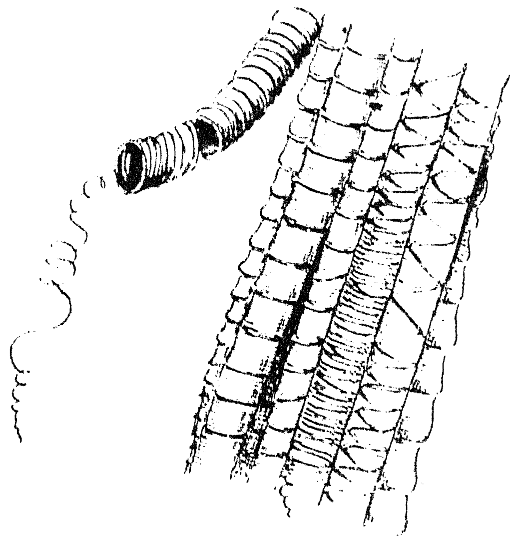
Plantain leaves with the "green threads" hanging out from the broken stalks.

easier to manage. Then, if I pull one to pieces with needles, and examine a morsel of it through my microscope, I am sure to find some of these curious tubes.

See, this one has a fibre coiled up as close as possible inside it, throughout its whole length. One of them has been torn by my needles, and the fibre has come out of its tube, and partly uncoiled, looking like a delicate tendril. In another the fibre is quite loosely coiled, and a third has only **rings** inside it.

These tubes are called **vessels**. They are formed by the union of a number of cells which happen to be placed end to end. The partitions between these cells break down and disappear, and a long vessel is thus formed. The curious coil of fibre within these tubes is (as usual) the work of the protoplasm.

FIG. 28.



Vessels from the fibre of a plantain leaf, as seen through the microscope.

Sometimes only rings are formed; and, indeed, in plant only just far enough up the scale of life to have such vessel this is the usual arrangement.

Sometimes, as we have seen, a complete, and even occasion ally a **double** coil of fibre is produced, which can be pulle out of the tube.

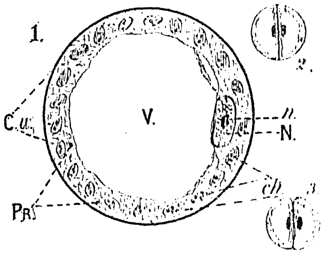
Sometimes, again, the thickening is laid down nearly a over the walls of the vessel, the tiny unthickened spac between looking like dots or pits. There are many varieti of appearances, which are all caused by the different mann

in which the thickening layer is deposited on the walls by the protoplasm.

"And what is the use of these vessels?" you ask.

It has long been a disputed point, but some experiments* have, it is generally considered, proved that they serve as channels to help in the distribution of the sap (and also of certain gases taken up by the roots) to the cells. If this be so, you will see that many plants (though not all) have a certain number of "passages" in their "house," after all, to bring the food-supply to the doorless chambers. But certainly none are provided with such a network of "passages" as is the case in the "house" of the animal.

FIG. 26.



1. Diagram of a single-celled plant.
2 and 3. Ditto dividing.
C.w. Cell wall. Pr. Protoplasm. V. Vacuole.
N. Nucleus. *n*. Nucleolus.
ch. Chlorophyll.

Roughly speaking we may say:

(1) The thin-walled, more or less rounded cells are used mostly for the absorption, manufacture, and storage of the plant's food.

(2) The narrow, thickened cells for giving strength to the various parts.

(3) And the vessels for carrying and distributing the sap and gases amongst the cells.

One more question we must ask before we close.

How does the plant grow? The tiny seedling can have but a small number of cells, compared to those in the full-grown tree; how do the cells multiply?

It is a simple process—none could be simpler.

The protoplasm of each cell, as it reaches a certain size, divides into two (or sometimes more) portions; a new wall is

* Made by Mr. Herbert Spencer.

built up between these portions, and each becomes a separate cell.

These new cells then set to work to grow until they also arrive at the stage when their size renders it necessary for the protoplasm to divide into two or more separate masses;* and so the multiplication of the cells and the growth of the plant goes on.

There are various different manners in which this division of cells is effected, but we must not stay to speak of them to-day; and the principle is the same in all—growth by division of the protoplasm, and the consequent multiplication of cells.

SUGGESTION TO THE TEACHER.

In order to study the frame-work of plants, let the children collect leaves and make careful drawings of their "ribs" and "veins," noting the great variation in the arrangement of these in different plants. It would be desirable, if possible, for the children to reduce leaves, seed-vessels, etc., to skeletons, but the process is too tedious and delicate for most children to manage. A recipe is however appended.

Steep the leaves in rain water, in an open vessel, exposed to the air and sun. Water must be occasionally added, to compensate loss by evaporation. The leaves will putrefy, and then their membranes will begin to separate. Then lay them on a clean white plate filled with clean water, and, with gentle touches, take off, with a stiff paint brush, the external membranes, separating them continually near the middle rib.

* The necessity for the fission of the cells, when they reach a certain size, arises out of the difficulty of supplying the protoplasm with food when its bulk becomes too great, relatively to the wall-surface, which acts as the medium for the conveyance of the supplies.

LESSON XI.

HOW THE PLANT FEEDS.

WE come back to-day, children, after our journey through the plant's green body, to a pressing question of daily life, which we all of us have to consider two or three times a day, at least!

We have considered it already to some extent in our Fourth, Fifth, and Sixth Lessons, under the head "Assimilation." We learnt in Lesson IV. which were the organs of absorption and assimilation in plants, and in what form the raw material was taken in by them.

Lesson V. described the manufacture of the food, and its storage in various parts of the plant; and gave details as to the plant's powers of abstracting the carbon from the air, for its own use, and to our great advantage.

In Lesson VI. we spoke of the substances made in the "green factories," and considered their uses from our own point of view, and that of the plant.

In Lesson IX. we examined into the elements of protoplasm, and saw whence these materials were obtained by the plant for its sustenance and growth.

We have learnt, then:

(1) That the *root* and *leaves* are the *principal* organs of absorption and assimilation.

(2) That *substances* can only be *absorbed* by the plant in the form of *liquids* or *gases*.

(3) That the *raw materials*, taken in by the root and leaf, are afterwards *prepared* for use by the *action of the cells* of

the leaves under the *influence of sunlight;* and that, finally the *surplus* of the food (forming various compounds, differing according to the nature, conditions, and circumstances of the plant) is *stored away* in various parts of the plant for future use

(4) That the *elements* of protoplasm are *carbon, oxygen hydrogen*, and *nitrogen*, with a minute quantity of *sulphur* and *phosphorus;* and that of these the *first* is taken in principally by the *leaves*, from the *air;* the *two next*, as *water*, by the *roots;* and the *three remaining elements*, in various combinations and solutions, by the *roots*, from the *soil*.

The question that remains for us to ask to-day is:

"How does the plant feed?"

First, however, I have one word more to say as to the materials of its food.

The four principal elements of protoplasm are the mos important of these by far, but I must not let you think the are the *only* substances which are needed for the plant' healthy sustenance. Quite a long list of **mineral** sub stances are to be found in minute quantities in plants; an small though the quantity may be, some of them are gener ally necessary to the very existence of the plant, as has bee proved by many interesting and curious experiments. Tha will not seem so strange to you when you consider that you own body cannot do without a certain mineral substance which you eat in very small quantities, and perhaps withou even knowing it, at almost every meal. I am speakin of *common salt*, which is really one of the *necessaries o life*.

Some child says: "I never eat salt, I do not like it!"

But you drink milk, do you not? and milk contains minute quantity of salt, as do other foods. Besides which a little salt is usually added in all cooking—even in th process of bread-making.

"And what are these mineral substances which are th

Well, we may mention first the elements of common salt itself (**chlorine** and **sodium.**)

Sulphur and **phosphorus** we have spoken of already, as entering into the composition of protoplasm.

Besides these, **potash** and **soda**, **lime**, **magnesia**, and **iron** will perhaps be those best known to you by name. **Silica**, or quartz, which forms the principal part of sand and sandstone, flint, etc., is a very important element in some plants. It is this stony substance which gives the firmness and the shiny appearance to straw, reeds, and grasses. It is said that in warm climates, during violent hurricanes, reeds have actually produced fires by merely striking together in the wind, owing to the amount of this flinty matter which they contain!

You will wonder how this most insoluble stony material can possibly be taken in by plants; but, though insoluble in water, silica, in combination with other substances, becomes decomposed, and rendered fit for the plant to absorb. Changes like this are constantly going on in the earth, the insoluble being converted into soluble matter by various agencies. Sometimes the mere chemical union of two elements is sufficient to produce a liquid or a gas which can be easily absorbed. (Oxygen and hydrogen form water; nitrogen and hydrogen produce ammonia; carbon and oxygen carbonic acid, and so forth.) But in spite of these natural chemical operations, much useful food remains in a solid and **insoluble** condition in the soil, and must be useless to plants as long as it remains so.

It is thought by some that the roots of plants, when they come in contact with such solid material in the soil, have the power to give out an acid juice, which melts up the delightful lump, and renders it "digestible" as we may say, that is, fit to be absorbed. Whether this observation be correct or not, it is quite certain that the whole earth teems with a countless multitude of tiny workers, who are as busy

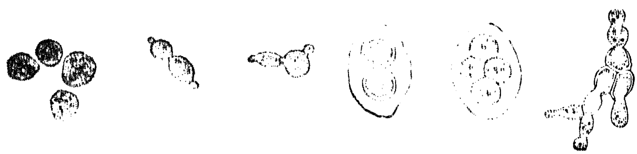
as they are small (and that is saying a great deal!) and who break up these masses of plant food and gradually render them soluble and available for the use of the hungry roots.

What useful little agents! What are they?

Well, they are the very humble relatives of the plants to which they minister.

Too minute to be seen except by the aid of the microscope, very simple indeed in form and construction, quite at the bottom of the scale of life, these little atoms still are numbered amongst Life's children, and have their place in

FIG. 27.



The yeast plant, and its method of growing and multiplying. Magnified.

the Vegetable Kingdom, and their special works—and some of them most important ones—to do. As an example of this class of tiny workers, I may mention the **little yeast plant**, which, by its growth and rapid multiplication produces the commotion and changes which we call fermentation in the juice of the grape or malted liquor, converting the sugar into alcohol. By the agency of this tiny microscopic plant, we are thus furnished with wine and beer.

Now that we have seen the materials of plant food rendered soluble and ready to be absorbed, we are prepared to ask the question: "How does the plant feed?"

How do you and I take in our food?

It is simple enough, you think; we just open our mouth and eat it!

But let us think over the process a little more carefully. Suppose one eats a piece of bread. The bread enters the mouth in a solid form. There it is ground up by the teeth

and mingled with the fluid in the mouth, which partly digests it, and changes the starch contained therein into sugar, as I told you in a former lesson.

Sugar, you know, is soluble, though starch is not; and, on entering the stomach, that part of the starch of bread which has been converted into sugar is ready to be absorbed into our blood.

How is this accomplished?

Numbers of small blood-vessels are situated all round the walls of the stomach, ready to absorb any part of the food which has been properly melted up and prepared to enter the blood; but these minute tubes have no opening; the membrane which forms their walls has no break in it. You see it is the old story again of the doorless cells, is it not? and the only way is through the walls! And *through* those walls of membrane it is that *the food* has to *penetrate*.

Now you will easily see that a bunch of little rootlets in a moist and fertile soil are in precisely the same case as the network of little blood-vessels in the stomach. The food is there, suitable in kind, and in liquid form, only waiting to be absorbed; but how shall it enter the closed cells of the thirsty rootlet?

People used to think that the tips of the rootlets had tiny holes, and that they sucked up the food like sponges; and so they called the root-tips **spongioles**, and you may hear the word to this day, though we know better now.

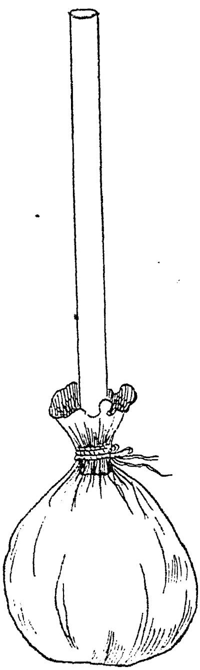
No! It is not the plant which **sucks**, but rather the water which **soaks**. It penetrates the cell by soaking through the cell membrane, or wall, for which it has what is called in chemistry "an affinity," or, as you may say, to make it plain to yourself, a **liking**.

To understand this matter better I think you must try one easy experiment. Get a long glass tube, and tie a bladder tightly over one end of it, in such a manner that the bladder forms a little bag opening into the tube.

Now fill the bladder with some syrup made of sugar and water, and plunge it into a bowl of pure water, securing the tube in an upright position, with the bladder under water. Leave it thus for a short time.

Now what has happened?

FIG. 28.



The tube with the bladder tied over it.

"Why the syrup has filled the bladder quite full, and is rising up into the tube!"

Well, the syrup cannot have increased in quantity, can it? So it must be the water out of the bowl which has penetrated through the bladder, or "membrane," to mix with the syrup.

This passage of fluids from without, through an intervening membrane, to the interior of the cell, is called **osmosis**; and you must notice that it depends principally on two conditions. First, the fluid outside the skin or membrane must have "an affinity" (or **liking**) for the kind of membrane which it is to penetrate.

And, secondly, the fluid inside the cell must be *thicker* than that outside, and the two fluids must also have *an affinity for each other*, and be able to mix when they meet.

This sets up a kind of current between the two fluids, and, at the same time that the thin fluid is hurrying through the membrane to reach the thicker one inside, the latter is also passing (though much more slowly and in less quantity) from within to without the membrane to join its friend, the thinner liquid.

Now we shall see that all these conditions are fulfilled both in the case of the blood-vessels in the stomach, and the root-

In the case of the blood-vessels, the membrane, of course, is supplied by their delicate coating, for which the solution of sugar has a strong affinity; and the sugar hurries to soak through this membrane and join the blood within it.

In the case of the rootlets, the cells just above the root cap have very thin and delicate walls, which are easily permeated by the water from the soil, carrying various substances in solution.

The water is thinner than the semi-fluid, jelly-like contents of the cells of the plant, so the necessary current is established, the water hastening to soak the cell-walls, for which it has the necessary affinity, and to join the thicker fluid within. At the same time, a small quantity of the contents of the cells escapes into the soil, where it goes to join its friend, the water. Thus you will see how it is possible that the acid juice we spoke of may be given out by the roots of plants for the "digestion" of lumps of food contained in the earth.

When the water has entered the first cell, as I have described, you can easily understand that, by exactly the same process, a part of it will pass through the walls of that little chamber into the neighbouring one, and thus continue its course throughout the plant, bringing supplies from cell to cell, or, sometimes, more rapidly, by means of the long vessels which I have before described.

Not liquids only are thus taken up by the roots, but also some gases, contained in the soil, enter the cells by the same process as the water, and are carried along through the cells and vessels with the **sap**, as the food-bringing juice is called.

Plants, you see, have no circulation such as ours; no such definite system of pipes or tubes, through which the nourishing blood is pumped to feed every hungry cell in the body. Nevertheless, it is astonishing how rapidly the liquid, taken in by the roots, ascends from cell to cell, or cell to vessel, when

—through what part it descends again to all the growing portions requiring nourishment.

On the whole, it is believed that the *upward course* is mainly through the *newer* part of the wood of the trunk (not the layer next to the centre of the stem), and that the *descent* takes place through the *tissues close underneath the bark*.

But, once again, remember that there is **no definite set of vessels** to carry the ascending sap, distinct from those conveying the descending food; so you must not think of the circulation of the sap in plants as being exactly the same thing as the circulation of our blood.

In concluding our lesson for to-day, let us put the processes of the feeding of the body in animals and in plants side by side, and compare them.

In Animals the food is taken in by the mouth, in solid form; is rendered soluble by various processes in the mouth, stomach, and intestines; is absorbed by the blood-vessels by osmosis;* is carried with the blood to the lungs, to be mixed with oxygen; and, lastly, is pumped, with the rest of the red nourishing blood, to every part of the body.

* We need not refer to the lacteals, as their contents are afterwards discharged into the blood.

In Plants the food is taken in, by roots and leaves, in liquid or gaseous form, by osmosis. The liquid taken in by the root is passed from cell to cell by the same process of osmosis; it passes up to the green leaves; is there prepared (with other matters taken in by the leaves) for the use of the plant, and thence disperses and descends to nourish every part of the vegetable body.

SUGGESTIONS TO THE TEACHER.

Let the children study the principle of osmosis for themselves; trying the experiment mentioned in the lesson, not merely with water and syrup, but substituting other liquids for these according to their pleasure, and noting carefully the results in the different cases.

All that would be required for this would be some sound bladders, and plain glass tubes.

LESSON XII.

THE GREEN LEAVES AND THEIR WOR

1. *As Organs of Transpiration.*
2. *As Organs of Absorption.*
3. *As Organs of Respiration.*

OF all parts of the plant, the green leaves seem, or whole, to be the hardest worked. Their duties, indeed so many that I have resolved to spend our two rema lessons in considering them in order, one by one.

To me it is a labour of love, for the very look of leaves, waving in the sunshine, seems to bring a soot sensation of peace and health, and recalls invariably beautiful words: "And the leaves of the tree were fo healing of the nations."

That this is not a wholly imaginary feeling, you perhaps agree with me when we reach the end of lessons.

Many trees and shrubs lose their leaves in the wint you well know; and in all cases the summer is by fa most busy season for these untiring little workers; in many of their functions can only be properly fulfilled there is some warmth and sunshine. We will arrange many duties under five different heads, and will conside green leaves first

As Organs of Transpiration.

We have spoken of the rapid passage of the water up by the roots from cell to cell, throughout the

Supposing there were no means of getting rid of the superfluous moisture, what would happen?

At certain times the plant would become gorged with water. The contents of the cells would then be so much diluted that they would be as thin as the liquid in the soil, and so no fresh food could come in by the process of osmosis. Things would be at a standstill in the plant, and such a state of stagnation would be very dangerous to its life.

The green leaves guard against this by allowing the superfluous water to evaporate through the membranes of their cells, as they spread themselves out in the warm sunshine. Thus the balance of things is restored; the cell contents become thicker as the water is withdrawn, and a fresh current, containing fresh food, is established from the cells of the rootlets to those of the topmost leaves.

Thus the leaves have a duty something like that of our skin, which is one of the means by which superfluous moisture is removed from our system.

You will now be able to understand why we often see the leaves of a plant flagging on a hot, dry day, or in a warm room. The thirsty air is drinking the water from the cells at their surface more rapidly than the fresh supply from the roots can be sent up to fill the little cisterns, and so they get empty, and the plant droops.

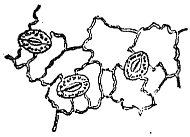
Plants intended by Nature to live in hot, dry soils, such as sandy deserts, have **thick** succulent leaves, capable of retaining the water in the inner cells of their fleshy substance; and the "skin" of their leaves is thicker than that of ordinary plants, and does not easily allow the moisture to escape. Thus Nature adapts her children to their surroundings.

But the business of the leaves is not solely, or principally, to get rid of unwanted material. As we have seen before, they, as well as the roots, are **organs of absorption**, and it is their duty to take in raw material from the air, as the

They are usually open by day, in favourable weather, and closed at night.

By these little windows some of the work of transpiration is effected, and it is to be noted that few or none are to be found in plants whose home is in the hot and arid desert.

FIG. 29.



Stomata, Magnified.

They are to be found in by far the greatest numbers on the **under** sides of leaves, these having generally thinner and more delicate coverings than the upper parts.

Now, it is principally through these little windows that the gases and vapours, required for the plant's nourishment, are taken in from the air.

You have not forgotten how the green leaves absorb the carbon in this manner, have you? And it seems to me that the best moment has come to stop and explain, as I promised to do in a former lesson, exactly what this kindly work is, which the leaves do for us when they drink in the carbon from the air, thus "purifying" it for our use.

You are best acquainted with carbon as **fuel**, are you not? Charcoal, coal, wood, all these contain much carbon, which makes them useful for burning in the fire. Now, this is just what carbon is required for in our bodies; it is wanted as fuel.

"What is the fire that burns this fuel?" you ask.

It is oxygen, the "good part of the air," as we have called it.

When the oxygen in the air, which is taken in by our lungs, comes in contact with the carbon in the tissues and blood of our bodies, it mixes or combines with that carbon in a manner which has practically the same effect as **burning** it. Heat and force are produced, the tissues are destroyed, (you will here be reminded of our constant need of fresh food to make new tissue or substance), and a gas is produced which is the same as that produced by burning wood or coal in an ordinary fire.

This gas has to be got rid of, and we breathe it out from our lungs continually. It is the **carbonic acid gas** of which I told you in that former lesson.

Now you will perceive that, although this gas is a combination of carbon and oxygen, neither of these elements is of any use to us if breathed in again in this form; for the carbon has been already "burnt" by the oxygen, so to speak. That is to say, the two elements have met and combined, the resulting heat has been produced, and now they are of no more use to us as long as they remain combined thus.

If we had to breathe pure carbonic acid gas we should instantly die, in spite of the oxygen contained in it, because the oxygen could not free itself from the carbon and come to consume the fuel of our tissues, thus producing the heat and force necessary to carry on our life.

At this point the kind green leaves come to our help. "You cannot use that carbonic acid gas," they say, "give it to us."

Welcome to it, indeed, dear leaves, but what can you do with it?

"We will take it into our cells," say the leaves, "and, by the help of the blessed sunlight, we will separate those two

elements which this gas contains. You shall have the oxygen which you need to maintain your life, and we will keep the carbon to build up our green bodies."

Wonderful leaves, can you really do this? What should we do without your aid? The carbonic acid gas would be constantly increasing, and we should be helpless to separate its elements, though dying for want of carbon as fuel, and oxygen as fire, to maintain our life. This work of yours is a double blessing; you store the carbon in your tissues for our future use, and you free the life-giving oxygen for our immediate needs.*

But do you need no oxygen yourselves?

"Oh yes. **No life** † can be maintained **without oxygen**; besides which it is wanted, in certain quantities, for most of our manufactures. We shall keep a small portion of that which we absorb from the air; but this is not our only means of obtaining it. Our little servants, the white roots, are constantly drawing water for us out of the soil, and, when it reaches us, we do with it as we did with the carbonic acid gas. We take it into our cells and expose it to the blessed sunshine, and, by its help, we separate the little molecules of water into their elements, oxygen and hydrogen. Thus we have plenty of oxygen; and as to the hydrogen, we mix it (or, as your chemists ‡ say, 'combine it chemically') with the carbon and make some wonderful substances out of the combination. But this belongs properly to our manufacturing business, and you have not come to that yet."

No, dear leaves, we must first ask a few more questions about the oxygen, and why you absorb it.

* Water plants have a similar purifying effect on water, by abstracting the carbonic acid it may contain, and freeing the oxygen.

† Generally speaking; though there may be some exceptional cases of microbes existing without it.

‡ The technical meaning of the word "chemist" should be explained, lest the children think we are speaking of a purveyor of drugs.

And this brings us, children, to the consideration of leaves as **organs of respiration**, or **breathing**.

All day long the green leaves are occupied, as we have seen, in withdrawing the carbonic acid gas from the air, and separating it up into its elements. But, for this process, two things are necessary, namely, **light** and **chlorophyll** (which you know is the green colouring matter of the leaves). How, then, about the night time, and how about the parts of the plant which are not green? Is the green world idle all night, and have those parts of the plant which are not green no work to do?

Nay. All Life's children have their work for each hour of their lives, though it may be different at different times.

When night falls, the cells which absorb and split up the carbonic acid must rest from that good work; and now they truly **breathe** more like animals. In fact they take in oxygen, and give out a small quantity (though not nearly as much as they absorb during the day) of carbonic acid gas.*

What do they want with this oxygen? The factories are not working at night, so it cannot be needed for combination with other elements to form food substances.

What do *we* want oxygen for? You remember it is the

* This true "respiration" of plants is supposed by some to go on all day as well as at night, and in the green parts, as well as in those not so coloured, simultaneously with the other process of absorption of carbonic acid gas and liberation of the oxygen; the chlorophyll, in the case of the green portions, having the power to regulate and balance these two processes, the former of which produces heat and force at the expense of tissue, whilst the latter provides the material for the repairing of the tissues, and for their growth. According to this view, plants **breathe** at all times as we do (though more feebly, owing to their stationary and less active life), and **feed** during the day upon the carbon which they obtain by the disintegration of carbonic acid and consequent liberation of oxygen.

It has been thought better, however, in these lessons to avoid all reference to difficult or doubtful points, in order not to confuse the children's ideas; consequently this question is not touched upon here.

great means of maintaining the heat of the body, by "burning" up the "internal fuel," as we called it.

Well, there is no life without *some* heat, and though perhaps you never realised that the body of a plant had any warmth, yet so it is; and the oxygen is required for exactly the same purpose as with us—namely, to keep up that degree of warmth which is necessary for the maintenance of the life. Plants, however, require much less oxygen to support their cool and quiet lives than we do for our more active existence; and, as we have seen, they require a large supply of carbon, which they are busy gathering from the air and storing up all day long.

Note that *oxygen* is required for the production of *heat* and *force; carbon* for the *building up* of the tissues and for *growth.* We shall expect, then, that where a special effort has to be made by the plant, more oxygen will be required; and thus you will not be surprised to hear that, during the **germination** of seeds, and the **flowering** and **fruiting** of plants, oxygen is taken in, in considerable quantities, and carbonic acid given out. In fact, germinating seeds, flowers, and ripening fruits **breathe** as we do, and actually give out heat, which may be tested by a thermometer. I have myself tried the experiment with the flower of an oleander, in my room, by holding a common thermometer in such a way that the bulb touched the centre of the flower, taking precautions, at the same time, that neither my warm hand, nor the sunshine, nor any other cause should influence the quicksilver. In a few minutes a rise of more than a degree was recorded. Very much greater rises of temperature than this, however, have been observed to be produced by the flowering of certain plants.

You see from all I have told you, that it is only the green parts of the plant which have a purifying effect upon the air, and these only in the day-time. Flowers, and all parts not coloured green, take in oxygen as we do, and give out carbonic acid (though in smaller quantities than is the case

the earth" is—in our land—almost suspended. Then it is that we have to thank the great winds of God, which sweep across to us from warmer climes, where the sun shines, out of a cloudless blue, upon a luxuriant wealth of foliage, and an inexhaustible supply of oxygen is ceaselessly being rendered up to the glowing air from the myriads of dancing leaves.

These same winds bear away our excess of carbonic acid to feed the hungry vegetation of tropical lands, and so the balance of things is maintained.

We must close our lesson here; but I think you will be disposed to agree that, after all, I am not too fanciful in my belief that the leaves of our summer-clad trees bring health and refreshment, and that indeed "the leaves of the trees are for the healing of the nations."

SUGGESTION TO THE TEACHER.

The children might make experiments to test the amount of oxygen given out by different parts of a plant, thus :

Let them take a bowl of **fresh spring** water, and immerse in it the green leaf, root, stem, flower, or whatever part is to be tested, so that it is completely covered by the water.

Now let the bowl be exposed to sunlight. If, after a time, a stream of little bubbles rises to the surface, these bubbles will be pure oxygen, produced by the decomposition of the carbonic acid contained in the water.

The experiment should then be tried of removing the bowl into the shade, and observing whether the bubbles still continue to rise. The result of the observations made should be brought in writing.

N.B.—These experiments are far more likely to be successfully made if *water*-plants are used. If leaves of land-plants are employed they should be soaked for a day before the experiment is tried.

LESSON XIII.

THE GREEN LEAVES AND THEIR WORKS (continued).

4. *As Organs of Manufacture.*
5. *As Organs of Digestion.*

As Organs of Manufacture.—We have arrived at our last lesson, children, and we are to spend it, not unprofitably, as I hope, in the consideration of the works of the dear, busy, friendly, green leaves.

I want to take you with me to the "green factories" once again. You will not fear lest you may be deafened with the noise, or covered with dust; you know Nature's quiet ways of doing her great works by this time.

See! the raw materials are being brought, by many and various channels, to the great manufactory. Through cell and vessel, along ways and byways, through those little open mouths, the stomata, or permeating the delicate membranes of the surface cells—the supply is constantly arriving. It is not food ready for use, remember, it is only the elements of plant-food. And now we are at the threshold of the "green factories" where it is prepared. Nowadays, in this advertising age, when every manufacturer vies with his rival as to which can produce the most striking and startling "attention-fixer," and when nothing can succeed, apparently, until the public have learnt to know its name to weariness, nowadays every manufacture of the smallest importance must have its ingenious and elaborate advertisement. So man thinks and so he acts.

But Nature never advertises herself; and, if we want to know what she is doing, we must take the trouble to *go and see.*

Here, however, I think, for your benefit, we will put up one advertisement over the door of the "green factories"; and let us write it in very big letters so that we may feel that it is very important, and always to be remembered.

Here it is:

CELLS provided with CHLOROPHYLL are the ONLY AGENTS for the manufacture of food from raw material.

FIG. 30.

Cuscuta europæa (Greater Dodder). Found on nettles, vetches, etc. Example of a plant *without green cells*, living entirely upon the food prepared by the plant about which it twines.

That "Only Agents" looks very business-like, does it not? It is rather a favourite expression in ordinary advertisements, but in this case it is no false pretension, but a matter of real fact.

Every part of the plant which is not coloured green must depend entirely for its food-supply on the cells containing those minute atoms of colouring matter called chlorophyll; and every plant which has no such cells—the mushroom and toadstool, for instance—must live on food which has been prepared originally by such cells—decayed animal or vegetable matter, for instance. In fact, all cells not containing chlorophyll are dependent on those that have it.

We human beings, of course, are entirely dependent on those green leaves with their atoms of chlorophyll.

What! You do not like this dependence of one upon another? You want to be free and independent, and to owe nothing to any one? Then you want to go back to the very lowest step in the scale of life, and to take your place amongst those comparatively independent little cells, each

of which "does everything," and can exist without aid from its neighbours. No. Let us follow wise, kind Nature, who teaches us that co-operation is the law of the higher life, and that it is by combining one with another, and interchanging services, that we must rise.

The flower must depend on the leaf for its food, and the leaf must depend on the flower for the reproduction of its kind; let each do his part faithfully, each being in turn the servant of his neighbour, and served by him.

But come back to the factories with me.

At night they will be closed; when the light fails, those busy cells will rest from their labour of preparing the food. Then will be the time to use up what has been made, and the growth of the plant will go on more rapidly than when its energies are employed in gathering and preparing the material for its sustenance. You may notice this specially in little seedlings, after the first provision of nature for them, in the seed, has been used up. Life is a struggle for them; all day long they are really too busy, collecting and cooking their food, to think about growing. But when night comes, and they must, perforce, rest from that labour, then, how they seem to shoot up in a few hours!

You hear people talk of "growing weather"; what sort of weather is that?

When the sun is veiled, and the light is dulled and softened; when the atmosphere is warm and moist, then the energy of work in the "green factories" is slackened, and the plant is wooed and encouraged by the balmy air to put forth its strength in growth. Then every little cell draws in the nourishment prepared for it, and grows, and divides, and multiplies; and the plant spreads and increases apace, for "it is very growing weather," we say.

At night—in warm weather at least—this process is always going on, more or less, and, in consequence, the food prepared in the day is partly consumed during the

Do not think that I can *explain* all that is going on here, although I know that the little molecules of chlorophyll and protoplasm are doing a marvellous work; that, by the aid of the sunlight, they are breaking up carbonic acid gas and water into their elements, and then combining the elements again (after setting free such portions as they do not require) in new and wonderful ways, which will render them fit for our use and that of animals.

Often and often have our chemists tried to imitate the marvellous processes which are going on in these factories. To some extent, after much patience and perseverance, they have succeeded; a few of the substances made here have really been imitated by man. Yet there is much—very much—which entirely baffles the cleverest intellect; and our men of science are still in doubt, and still disputing as to *how* the work is done in all its details.

I need not repeat our list of substances manufactured here, need I? You do not forget the starch, the sugar, the oil, and all the other substances we mentioned in Lesson VI.?

When you and I, or some animal, feed upon these foods, prepared for us here, what will be the result?

They will be "burnt" in our body to produce force and energy, will they not?

Then these quiet green plants are really the source—the

deep wells, so to speak—of all the energy and activity, all the life and movement of this busy earth.

That thought makes one pause, in a kind of solemn wonder, at the marvellous chain of life which links every mighty action and every heroic deed with the humble "green things upon the earth." Truly, as the well-springs of energy, they may, in those very noble deeds for which they supplied the power, be said to "bless the Lord, praise Him and magnify Him for ever."

But it is time for us to turn our thoughts to one more —and the last for our consideration—work of the green leaves.

As we turn from the "green factories" look up once more at our advertisement, and remember the great importance of those particles of green colouring matter.

If you see the leaves of your plants looking pale and yellow, be sure that, not only is it a sign of unhealthiness in the plant, but also it means that the power of manufacturing food is failing; and, unless you can find out and remedy the evil, the poor plant is in danger of dying of starvation.

Perhaps you have put it in too shady a place, or perhaps you have watered it too much or too little; whatever is the cause, the pale leaves are as much a sign of illness as pale cheeks would be with you.

We turn now to the office of leaves—

As organs of digestion.

The starch, we will say, has been prepared in the leaves.

If we examine the cells under the microscope, we shall see that they contain minute grains of starch imbedded in the protoplasm. Now, these grains of starch are not wanted here. Starch, you know, is "storage food," and not fitted or intended to be immediately absorbed by the plant; and it certainly must not remain in the factory, where it would be very

uch in the way. Some of it is wanted at once to supply e needs of the growing portions of the plant; and the emainder must be conveyed to the storehouses, wherever ey may be, to be laid by there for future use. But how is to travel? for you know well by this time that no solid om can pass from cell to cell, and the grains of starch hich each cell has manufactured are solid particles, though finitely small.

The difficulty is overcome by the presence in the cells of a bstance, formed in the protoplasm, called **diastase**, which s the power, under certain circumstances and conditions, changing the *insoluble starch* into a *soluble kind of sugar*, lled "glucose," or grape-sugar.*

Of what does this remind you, children?

It recalls the **digestion** of starch, in our mouths, by the operties of the saliva, which convert it into sugar. And at is exactly what the diastase in the leaves is doing. It **digesting** the starch (melting it up), and so rendering capable of travelling from cell to cell, till it reaches the owing points where it is required for immediate use.

Do you remember that, in Lesson VI., I referred to this me digesting power in the little embryo pea or bean, d explained how, by this means, it (and all other germin- ing embryos) were able to convert whatever store of starch ight have been laid up for them, in the seed, into a soluble gar?

This process of digestion must go on wherever food is id by, in store (for instance in all succulent roots, bulbs, bers, etc.), before the nourishment is available for the use the growing plant.

The unselfish leaves, however, do not perform this act of gestion for their own benefit, but merely as a means of nveying the food which they have manufactured to its stination. When it is to go to a point where growth is

* It is first converted into **dextrose**, then into **glucose**.

proceeding quickly, of course it is used up immediately on its arrival, and there is no question of storage.

But supposing it is to be sent to one of the storehouses, to be put by as reserve-food, what then happens when it reaches the end of its journey? It is in a state of solution, and it cannot be stored away thus.

There is nothing for it but to turn it back into starch again. This work is performed by some cells containing little granules of protoplasm, which exactly resemble those granules in the leaf-cells which first manufactured the starch, only that, in this case, they **contain no chlorophyll.** You see their duty is simply to "put the starch together again," not to make it out of the elements.

Conjurers who profess to be able to pass a teacup through a wall, are usually regarded as having performed the miracle (in appearance) by clever sleight of hand; but here is Nature performing, in actual fact, the marvel of passing a solid body like starch through many walls, one after another, and finally presenting it as solid starch again at the end of its travels.

This work of digestion is the last of those five activities of the green leaves, of which we had to speak. We have seen them (1) *relieving the plant of its superfluous moisture*, and thus encouraging the process of osmosis, which brings fresh supplies of food to every cell; we have seen them (2) *absorbing* from the air *vapours and gases*, and reducing the hurtful carbonic acid gas to its useful elements, thus *purifying our atmosphere*; we have watched them (3) *breathing* for the plant, to maintain its necessary degree of warmth; we have observed them (4) *manufacturing food* for the plant and for ourselves in their quiet factories; and, lastly, we have seen them (5) *digesting and distributing the manufactured food* to its various destinations.

Do they not seem to you perfect types of unselfish, untiring workers for others? and will you not love and rever-

ence the dear green leaves, and tend them carefully, if you have plants of your own?

We have come to the end of our course of lessons, children, but I hope you are far from being at the end of Nature's lessons. Let me point you to her as your teacher.

I can wish for you nothing better than to listen to her all your days, *reverently*, *humbly*, and *lovingly*; remembering always that her voice is the Voice of Him in whom we live and move and have our being; and that, however deceptive appearances may be, she can never be at variance with His true teachings and revelations, for He is in truth the God of Nature, and she is the expression of His Thought, thus made manifest to our senses.

SUGGESTION TO THE TEACHER.

Let the children search for plants which have *no* green coloured parts, and try to ascertain how they are living.

In many cases only fungi will be discovered, but a quick-eyed child may come across a parasitic plant, such as one of the dodders; or an autumn crocus, fed by the nourishment laid up in its corm by its now withered leaves.

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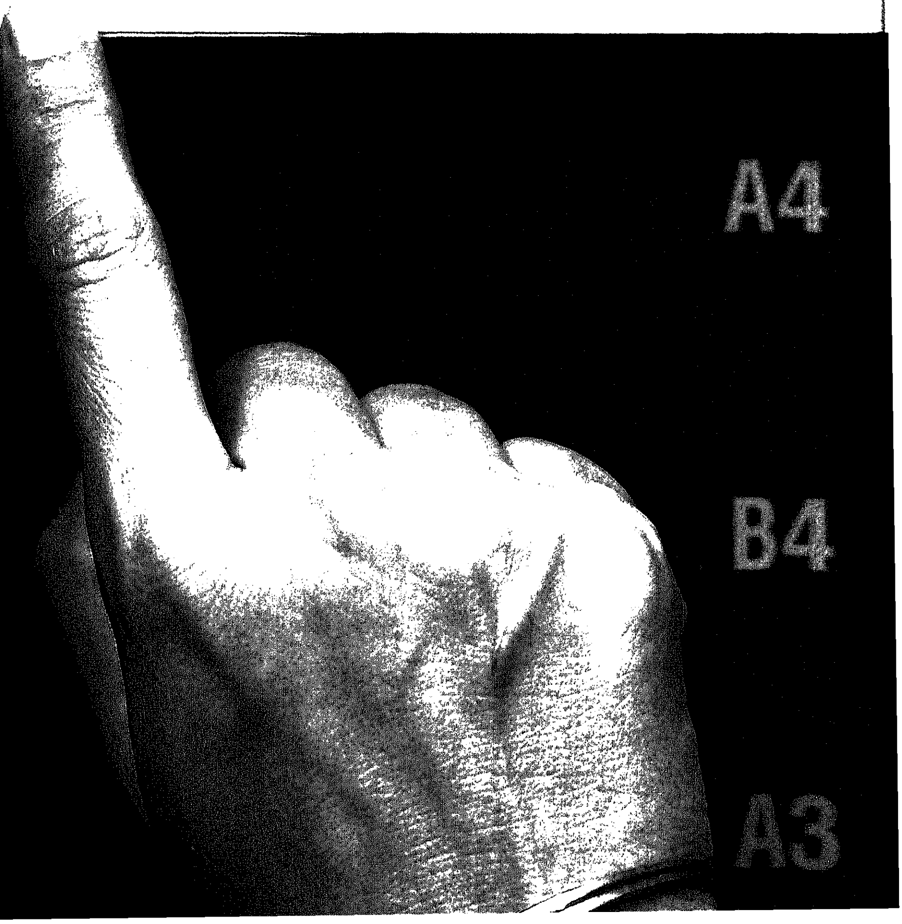
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